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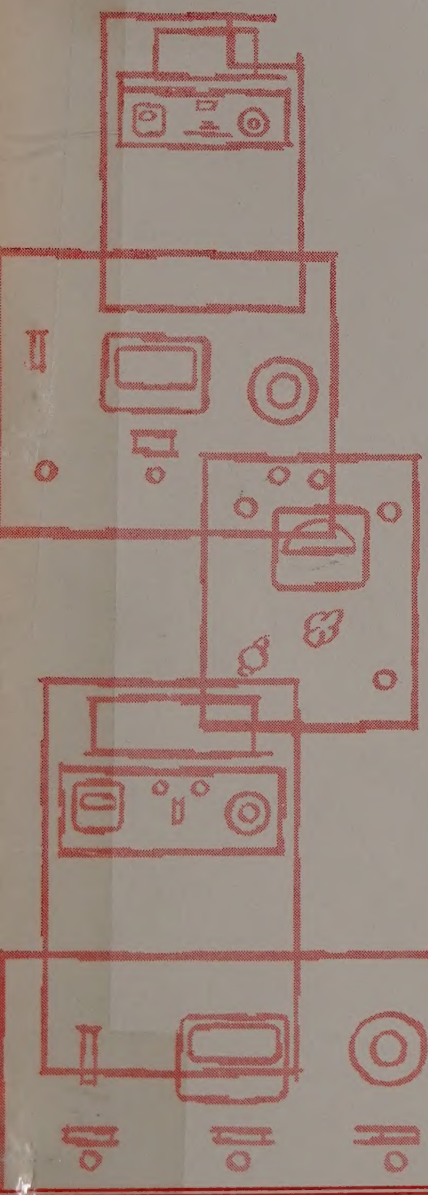


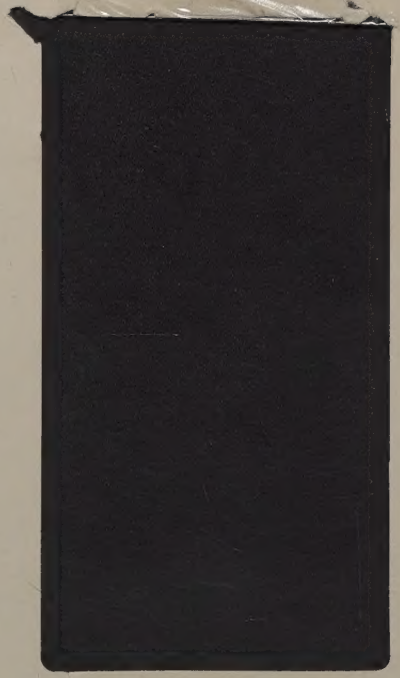
ASSOCIATED RESEARCH, *Incorporated*

3758 WEST BELMONT AVENUE • CHICAGO 18, ILLINOIS

MP MASTER
MA30108

INSTRUMENTS *for measuring:*

- Insulation Resistance . . the VIBROTEST®
- Ground Resistance . . the VIBROGROUND®
- Earth Resistivity . . the VIBROGROUND®
- High Voltage Breakdown, AC-DC . . the HYPOT®



OPERATING INSTRUCTIONS

MODEL 4642-M2 MOBILE AC HYPOT

INPUT: 230 V.AC, 60 Cycle, 1 Phase
OUTPUT: 0-5 KV AC
CAPACITY: 5 KVA Intermittent Duty
ADJ. CIRCUIT BREAKER: 100 MA to 1 AMP

CAUTION HIGH VOLTAGE

THE OPERATOR IS RESPONSIBLE FOR THE SAFETY OF ALL PERSONNEL WHILE USING THIS INSTRUMENT. DO NOT ATTEMPT TO CONNECT OR DISCONNECT ANY ITEM UNDER TEST WHILE THE INSTRUMENT HIGH VOLTAGE IS ENERGIZED. KEEP ALL PERSONNEL A SAFE DISTANCE FROM THE HIGH VOLTAGE OUTPUT WHILE MAKING HIGH VOLTAGE TESTS.

MODEL 4642-M2 MOBILE AC HYPOT

* * * * * * * *

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Replacement Parts List.....Section V

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ASSOCIATED RESEARCH, INCORPORATED

3758 West Belmont Avenue

Chicago 18, Illinois

Q-1174

April 4, 1962

SECTION I

SPECIFICATIONS

SPECIFICATIONS

MODEL:	4642-M2 Mobile AC HYPOT.
INPUT:	230 volts AC, single phase, 50/60 cycle through ten foot, three conductor line cord, with standard three-prong plug.
OUTPUT:	0-5000 volts AC.
CAPACITY:	5 KVA intermittent duty; 2 KVA continuous.
CIRCUIT BREAKER SENSITIVITIES:	Adjustible from approximately 100 milliamps minimum to 1 amp maximum. Instantaneous trip.
KV METER RANGES:	0-1 KV ± 30 volts, 0-2 KV ± 30 volts, 0-4 KV ± 60 volts, 0-5 KV ± 120 volts.
OUTPUT TERMINATION:	Shielded high voltage cable and ground terminal located on rear skirt of cabinet.
CABINET:	Mobile with semi-pneumatic tires and push handle.

SECTION II

GENERAL FEATURES

GENERAL FEATURES

"POWER" SWITCH

The "POWER" switch makes or breaks all input power to the instrument. The trip coil of this "POWER" switch is remotely controlled by the adjustable circuit breaker relay and turns OFF input power when an overload occurs.

"VOLTAGE" CONTROL

A continuously variable "VOLTAGE" control gives the operator smooth control of the output voltage from zero to maximum. This "VOLTAGE" control is equipped with a zero return interlock switch, making it necessary for the control to be at its zero output volts position before the high voltage control circuit can be energized. This prevents the sudden application of high voltage to the item under test.

"H.V." SWITCH

This three-position lever switch, operating in a 230 V.AC circuit, controls the energizing or de-energizing of the high voltage control circuit. With this switch in its center position, the high voltage control circuit is de-energized and no high voltage is available at the output termination, regardless of the position of the "VOLTAGE" control. In the UP position with the "VOLTAGE" control at zero volts, the high voltage control circuit will be energized and the lever switch will remain in this position until returned to center OFF by the operator. In the DOWN position with the "VOLTAGE" control at zero volts, the high voltage control circuit will be energized only as long as the operator holds the lever switch in this position.

"KILOVOLT" METER

The "KILOVOLT" meter meters the high voltage output from the instrument. It is connected directly across the output termination, thus indicating true terminal voltage irrespective of internal regulation. Three scales (0-1/2/4/5 KV) are provided for higher accuracy in reading when testing at voltages lower than the maximum range of the instrument.

"KV F.S." SELECTOR SWITCH

A four position rotary switch is provided for selecting the KILOVOLTMETER ranges. This switch selects meter ranges only, it does not change the output range of the instrument. For example, if 95% of "VOLTAGE" control rotation is required for 5 KV output, then approx. 75% rotation will be requir when the 4 KV meter range is selected, or approx. 40% for the 2 KV meter range, etc.

"BKR. ADJ." CONTROL

The circuit breaker sensitivity is continuously adjustable from approx. 100 milliamps minimum to 1 amp maximum. The "BKR. ADJ." control provides for this adjustment.

To adjust this control it will be necessary to connect a resistive load across the output. The value of this resistive load will be based on the current setting desired, between approximately 100 MA to 1 amp, at a voltage readable on the 5 KV range of the meter. For accuracy of setting, it is best to use a voltage readable at about 4/5 scale or higher (between 4 KV and 5 KV). Ohms law R = E/I will give the proper value of resistance to connect across the output termination, where E = voltage selected between 4 and 5 KV, I = circuit breaker current setting desired, and R = necessary resistance to be connected across the termination.

The dial of the "BKR. ADJ." control is calibrated in per cent from 0 "MIN." to 100 "MAX.". Set the "BKR. ADJ." control to "MAX." and increase the output voltage to the value selected above. Slowly rotate the "BKR. ADJ." control toward "MIN" until the circuit breaker trips. The circuit breaker is now set for the sensitivity required.

Sheet 3 of this section is a record sheet with factory calibrated points recorded. This sheet may be used to record other intermediate values selected in the field.

"POWER ON" AND "H.V. ON" INDICATORS

These indicator lights signal the availability of POWER input and HIGH VOLTAGE output respectively.

"SAFETY INTERLOCK" RECEPTACLE AND SAFETY FEATURES

The "SAFETY INTERLOCK" receptacle provides for interlocking the high voltage control circuit from a remotely located switch. This receptacle is electrically located in series with the high voltage lever switch, and has a jumper wire across the terminals of the mating plug as the instrument is shipped from the factory. To use the "SAFETY INTERLOCK", remove the twist-lock plug from its receptacle and remove the jumper wire from its terminals. Connect the wires of the remotely located switch to the terminals of this plug and re-insert the plug into its twist-lock receptacle. While the remotely located switch is open, the high voltage control circuit will be disabled and no high voltage will be available at the output termination, regardless of the setting of any other controls on the instrument. This switch must be closed in conjunction with the other conditions described under "H.V." SWITCH.

A thermally actuated manual reset circuit breaker protects the primary and control circuits against overloads.

The H.V. CABLE is shielded with its shield connected to cabinet ground for operator safety.

"OVERLOAD BKR. ADJ." CONTROL SETTING

CURRENT SENSITIVITY IN MILLIAMPS	PER-CENT INDICATION ON SCALE
100	0
250	79
500	84
750	90
1000	100

SECTION III

OPERATING INSTRUCTIONS

OPERATING INSTRUCTIONS

1. Place "POWER" switch in the "OFF" position.

2. Plug "INPUT CABLE" into a 230 volt, 60 cycle, single phase outlet.

3. Rotate the "VOLTAGE" control knob to its zero volts position (full counter-clockwise).

4. Place the "H.V." switch in its center "OFF" position.

5. Turn the "POWER" switch "ON".

6. Select desired KILOVOLTMETER range with "KV. F.S." selector switch.

7. Set adjustable circuit breaker with "BKR. ADJ." control as outlined in the GENERAL FEATURES section.

8. Connect the "H.V. CABLE" and the "GROUND" terminal to the item to be tested.

9. Activate the "H.V." switch to the UP position for continuous ON or the DOWN position for mementary ON.

10. Rotate the "VOLTAGE" control clockwise until the desired test voltage is indicated on the kilovoltmeter. If the insulation of the item under test fails, the "POWER" switch will trip "OFF".

11. To re-energize the instrument, repeat steps 3, 5, 9 and 10.

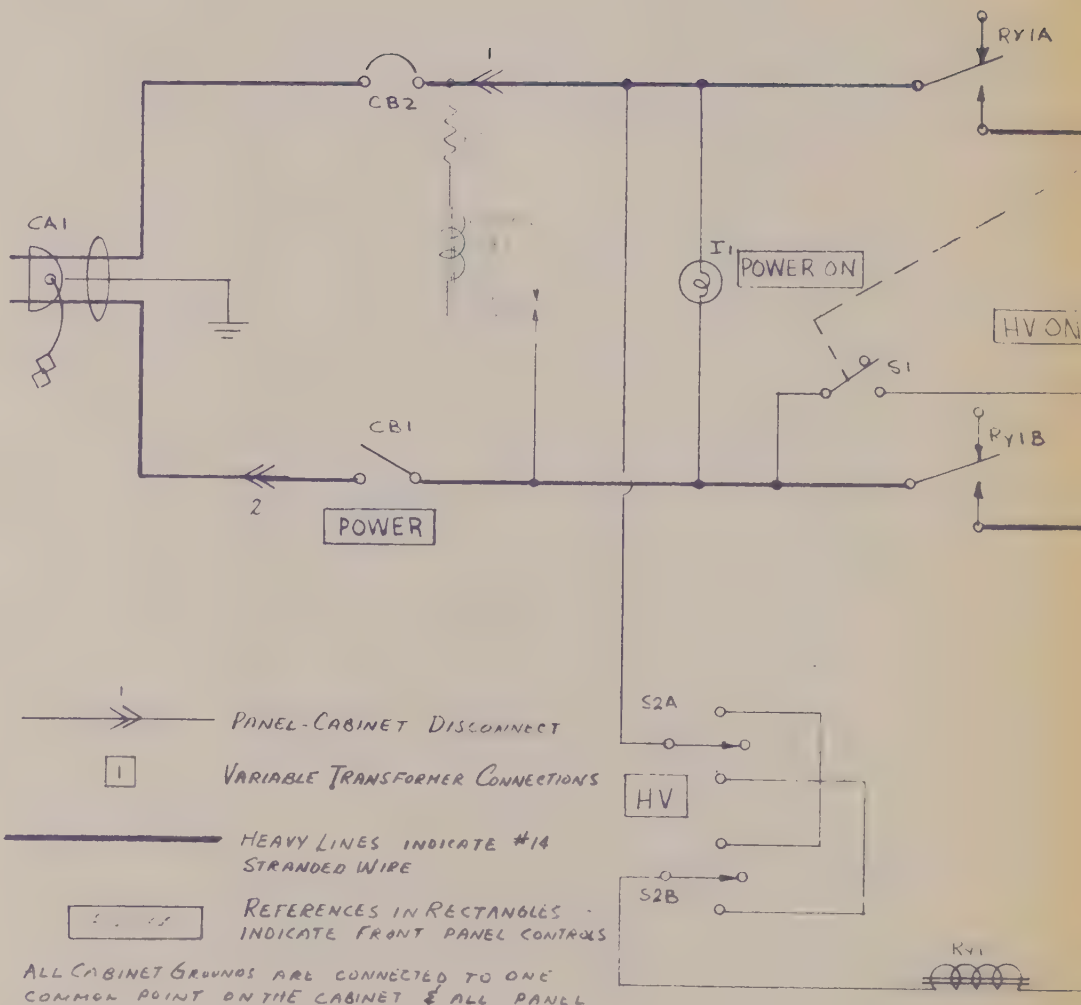
C A U T I O N

THE OPERATOR IS RESPONSIBLE FOR THE SAFETY OF ALL PERSONNEL WHILE USING THIS INSTRUMENT. DO NOT ATTEMPT TO CONNECT OR DISCONNECT ANY ITEM UNDER TEST WHILE THE INSTRUMENT HIGH VOLTAGE IS ENERGIZED. KEEP ALL PERSONNEL A SAFE DISTANCE FROM THE HIGH VOLTAGE OUTPUT WHILE MAKING HIGH VOLTAGE TESTS.

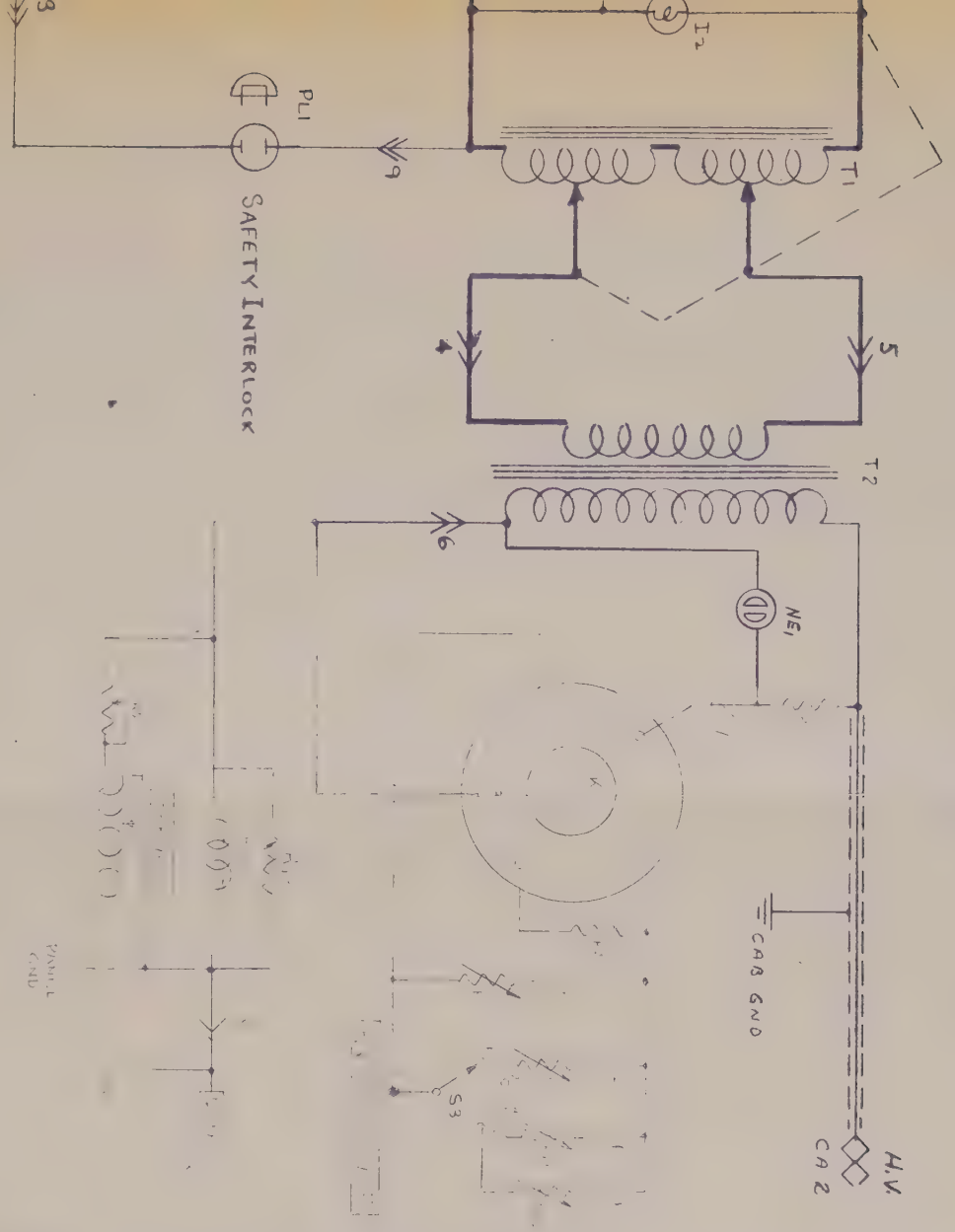
SECTION IV

SCHEMATIC WIRING DIAGRAM

USED ON



WG, CWD A-4580



	CHANGE	DATE	BY	APP.
	RELOCATED R13	5/22/62	JD	MK
	ORIGINAL ISSUE		JD	CW

TOL. FRACT. ±
DECIMAL ±
SCALE
MAT'L
FINISH
TOOLS

ASSOCIATED RESEARCH, Incorporated
"Precision Instruments Since 1936"
3758 WEST BELMONT AVENUE • CHICAGO 18, ILLINOIS

SCHEMATIC WIRING DIAGRAM
MODEL 4642M2 HYPOT

DWN	APP. CW
CKD. MK	SHT. 1 OF 1

DWG CWD A-4580

SECTION V

REPLACEMENT PARTS LIST

MODEL 4642-M2 - REPLACEMENT PARTS LIST

SYMBOL	PART NO.	DESCRIPTION
CA-1	10334	Cable, Input
CA-2	NSN	Cable Assembly, H.V. output
CB-1	P11780	Circuit Breaker, magnetic
CB-2	P14575	Circuit Breaker, thermal
I-1, 2	P11052	Lamp, indicator (H.V. & POWER ON)
M	P15192 w/S-238	Meter and Scale, KV meter
NE-1	P8591	Lamp, Neon
PL-1	P11729/P11730	Plug, Safety Interlock
R-1	P10586	Resistor, fixed; KV meter multiplier
R-2	NSN	Resistor, adj.; 50 ohms @ 50 watt
R-3	P8533	Resistor, fixed; C.B. current limit
R-4	P11821	Resistor, fixed; meter series
R-5	P10414	Resistor, fixed; meter shunt
R-6	P14743	Resistor, variable; meter shunt
R-7	P14477	Resistor, fixed; meter shunt
R-8, 10, 12	P14867	Resistor, variable; meter shunt
R-9	P8143	Resistor, fixed; meter shunt
R-11	P10853	Resistor, fixed; meter shunt
R-13	NSN	Resistor, fixed; 400 ohms @ 5 watts
RY-1	P14328	Relay, DPDT; H.V. control
RY-2	P14947	Relay, SPDT; output current overload
S-1	P10678	Switch, micro; zero return interlock
S-2	P10637	Switch, lever; H.V.
S-3	P14630	Switch, rotary; KV meter range
SH	NSN	Shield Can Assembly, meter
T-1	P14376	Transformer, variable "Voltage" control
T-2	P15193	Transformer, H.V.
T-3	P11654	Transformer, variable; "BKR. ADJ."
TER-1	10304	Terminal, ground

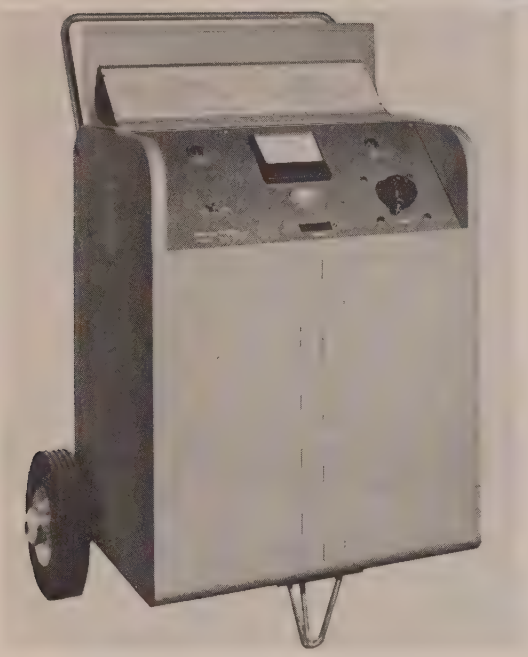
COMPONENTS NOT SHOWN ON SCHEMATIC WIRING DIAGRAM

P11047	Lampholder, white lens
P9492	Lampholder, red lens
14566	Lead, ground

NSN - DENOTES NO STOCK NUMBER. WHEN ORDERING THESE COMPONENTS PLEASE SPECIFY MODEL AND SERIAL NUMBERS ALONG WITH COMPLETE DESCRIPTION.

DWG. NO. CPL-B-4581
June 20, 1962

ASSOCIATED RESEARCH, Incorporated
ENGINEERING DATA SHEET



MOBILE AC HYPOTS®

0-5 KV

0-10 KV

0-20 KV

AT 1, 2, 5 OR 10 KVA

0-30 KV

AT 1, 2 OR 5 KVA

APPLICATION

TESTING OF LARGE ROTATING MACHINERY AND EQUIPMENT, LINE MATERIALS, SHORT LENGTHS OF CABLES, LIQUIDS AND INSULATING MATERIALS, OR WHEREVER AC TESTING WITHIN THE RATING OF THESE UNITS IS REQUIRED.

GENERAL FEATURES

INPUT: 115 VOLTS, SINGLE PHASE 50/60 CYCLES AC FOR 1 AND 2 KVA UNITS; 220 VOLTS, SINGLE PHASE 50/60 CYCLES AC FOR 5 AND 10 KVA UNITS. TEN FOOT, THREE CONDUCTOR INPUT LEAD WITH GROUND CLIP AND STANDARD TWO-PRONG PLUG.

OUTPUT: CONTINUOUSLY ADJUSTABLE FROM ZERO TO MAXIMUM VOLTAGE. KVA RATING IS FOR INTERMITTENT DUTY. CONTINUOUS DUTY RATING IS 40% OF LISTED VALUE. OUTPUT TERMINATION IS THROUGH SHIELDED HV CABLE 10' LONG AND GROUND BINDING POST TERMINAL. TEN FOOT DETACHABLE GROUND LEAD FURNISHED.

CONTROLS: ON-OFF SWITCH WITH PILOT LIGHT; "HIGH VOLTAGE ON" LEVER SWITCH FOR MOMENTARY OR SUSTAINED APPLICATION OF HV; "HV ON" PILOT LIGHT; VARIABLE OUTPUT VOLTAGE CONTROL WITH ZERO RETURN INTERLOCK; CIRCUIT BREAKER RESET.

METERING: 4-1/2" RECTIFIER TYPE KILOVOLTMETER CONNECTED ACROSS THE HV OUTPUT. ACCURACY ±3% OF FULL SCALE.

SAFETY FEATURES

CABINET AND PANEL AT GROUND POTENTIAL; CONNECTOR FOR REMOTE SAFETY INTERLOCK; HIGH VOLTAGE CIRCUITS AND EXTERNAL LOAD PROTECTED BY FAST-ACTING, MAGNETIC CIRCUIT BREAKER SET AT MAXIMUM RATED KVA (SET AT A LOWER POINT FOR SOME APPLICATIONS WHERE FAST BREAK AT LOWER VOLTAGES IS REQUIRED). PRIMARY CIRCUITS PROTECTED BY THERMAL OVERLOAD BREAKER; ZERO RETURN INTERLOCK TO PREVENT ACCIDENTAL APPLICATION OF HIGH VOLTAGE; SHIELDED HV OUTPUT CABLE OFFERS ADDED OPERATOR SAFETY AS WELL AS PROTECTION OF THE CABLE FROM MECHANICAL DAMAGE.

- CONTINUED -

SPECIAL FEATURES

EASY MOBILITY; VOLTMETER CONNECTED DIRECTLY ACROSS HIGH VOLTAGE OUTPUT; READINGS ARE OF ACTUAL TEST VOLTAGE APPLIED IRRESPECTIVE OF REGULATION OR LOAD. HIGH QUALITY, HEAVY DUTY TRANSFORMER HAS VERY GOOD CREST FACTOR.

CABINET DETAILS

GRAY LEATHERTONE FINISH, STEEL, MOBILE TYPE, WITH CABLE REEL AND DETACHABLE PUSH HANDLE. MOUNTED ON 10" x 2-3/4" BALL BEARING, SEMI-PNEUMATIC, PUNCTURE-PROOF WHEELS.

WIDTH (CASE ONLY):	23"
WIDTH (INCLUDING WHEELS):	32"
DEPTH:	21"
HEIGHT:	41"
CRATED DIMENSIONS:	29" x 36" x 45-1/2"
WEIGHT:	150 TO 250 POUNDS, DEPENDING ON RATING.

OPTIONAL FEATURES

THESE MOBILE AC HYPOTS MAY BE FURNISHED WITH ANY OF THE FEATURES LISTED BELOW AT THE CUSTOMER'S REQUEST (AT EXTRA COST).

1. 440 VOLTS, SINGLE PHASE 50/60 CYCLES AC INPUT.
2. MULTIPLE KV METER RANGES.
3. PLAIN PROD ON HV CABLE (5 KV MODELS ONLY).
4. PUSH-BUTTON PROD (TO TURN ON HV REMOTELY). ZERO RETURN INTERLOCK AND PANEL LEVER SWITCH MUST BE OMITTED IN THIS MODIFICATION. (5 KV MODELS ONLY.)
5. BURN TEST CIRCUIT. THIS OPTION PROVIDES AN AUXILIARY TRANSFORMER AND TWO OUTPUT LEADS TO GIVE UP TO 30 AMPS CONTINUOUSLY ACROSS A SHORT CIRCUIT. OPEN CIRCUIT VOLTAGE IS APPROXIMATELY 5 TO 10 VOLTS. ADJUSTABLE FROM ZERO TO MAXIMUM.
6. AC MILLIAMETER, SINGLE OR MULTIPLE RANGE (MINIMUM RANGE 10 MA FULL SCALE).
7. DUAL RANGE SECONDARY OVERLOAD CIRCUIT BREAKER. (FOR TRIP-OUT AT LESS THAN FULL RATING OF HYPOT; ESPECIALLY USEFUL ON LOW VOLTAGE TESTS.)
8. ADJUSTABLE SECONDARY OVERLOAD CIRCUIT BREAKER FOR PRESETTING MAXIMUM ALLOWABLE SECONDARY CURRENT.
9. ANY OF THE 5, 10 OR 20 KV MODELS LISTED MAY BE FURNISHED IN THE ARI DELUXE CONSOLE CABINET INSTEAD OF THE MOBILE CABINET. FOR 30 KV CONSOLE MODELS, SEE SEPARATE DATA SHEET.

INSTRUMENTS for measuring
ASSOCIATED RESEARCH, INC.
3758 W. Belmont Ave. · Chicago 18, Illinois
• Insulation Resistance . . the VIBROTEST® • Earth Resistivity . . the VIBROGROUND® • Special Instrumentation for Laboratory,
• Ground Resistance . . the VIBROGROUND® • High Voltage Breakdown, AC-DC . . the HYPOT® Production, and Maintenance Needs

Bulletin 5-15.4

ASSOCIATED RESEARCH, Incorporated
INSTRUMENT APPLICATION NOTES

Reprinted from "ELECTRONIC DESIGN"
February 1, 1961.

High-Voltage Testing:

It Can Be Nondestructive

Harold N. Miller
Vice President and Chief Engineer
Associated Research, Inc.
Chicago, Ill.

IS HIGH-VOLTAGE testing destructive or nondestructive? Both sides of that question are amply covered in published articles; the answer would seem to lie, in any individual case, in the material being tested and the method of testing.

Intelligent appraisal of the subject first requires understanding breakdown mechanism, or at least the main causes of insulation failures. Insulation breakdown is usually described as: a destructive discharge through the insulation, characterized by a disproportionately large change in test current as test voltage is increased. This surge is often referred to as an avalanche current. After a breakdown failure, it is usually impossible to restore voltage to the previous point. Breakdown may also be defined as: a rupture of the insulation that results in increased leakage current at a specified test voltage.

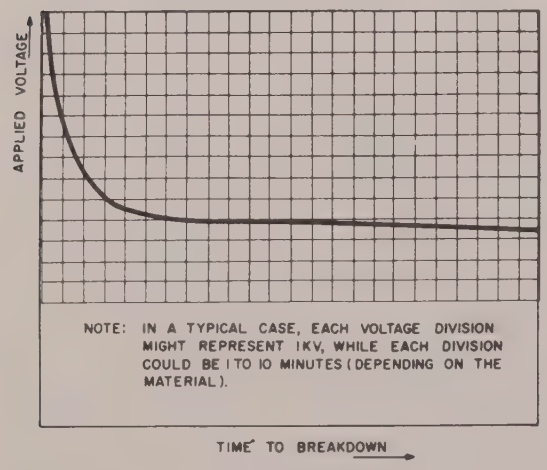

APPLIED VOLTAGE
NOTE: IN A TYPICAL CASE, EACH VOLTAGE DIVISION MIGHT REPRESENT 1KV, WHILE EACH DIVISION COULD BE 1 TO 10 MINUTES (DEPENDING ON THE MATERIAL).
TIME TO BREAKDOWN

Fig. 1. Applied test voltage versus length of time to breakdown.

Causes of Insulation Breakdown: Three Are Cited

Three main causes of failure are usually identified as:

*1. **Mechanical breakdown,*** caused by stresses set up by the applied voltage. This type of failure is much more likely to be prevalent with ac testing than with dc; it is often associated with impulse testing.

2. ***Thermal failure,*** due to insulation deterioration caused by internal generation of heat. This heat may be due to high leakage current, but more often is caused by conductors or other current-carrying parts operating hot. Thermal damage is cumulative with time.

3. ***Ionization failure,*** due to chemical deterioration of the insulation. This is usually caused by oxygen released during ionization of air in insulation voids or around the insulation. Deterioration caused by this chemical action is cumulative with time.

Since two of the three main causes of insulation damage show a cumulative effect, indiscriminative testing can eventually cause failure. Testing, properly done, however, would not be carried to levels that would result in any significant damage to sound insulation.

Voltage Endurance Can Serve As A Function Of Test Time

The voltage a piece of equipment can stand depends, to a great extent, on the length of time

that voltage is applied. This relationship is not linear, but has the general characteristics shown in Fig. 1. The exact shape of the curve (applied voltage vs length of time to breakdown) depends on the specific material under test, if the applied voltage is ac or dc, the shape of the test electrodes, etc. In all cases, however, the curve shows that, if the voltage is lowered slightly, the withstand time is increased greatly.

If the equipment is originally designed so the insulation can stand 120-130 per cent of the final test voltage for a reasonable length of time (several minutes to an hour), almost indefinite testing at the lower voltages can be done without damage. Recognizing this characteristic of insulation leads many specifying agencies and manufacturers to call for in-service test voltages of 60 per cent to 80 per cent of the factory test values. This voltage-vs-time condition is also specified or implied in many specifications that permit tests at a given voltage for 1 min or, alternatively, a 25 per cent higher voltage test for 5 sec. In the case of equipment already designed or in production, the test voltage the insulation can stand for the long time period can be experimentally determined. Then, running production or maintenance tests at 60 per cent to 80 per cent of this voltage would be safe.

With the present state of the art (where even thin films of insulation may stand many hundreds of volts per mil), it is almost mechanically impossible to have a sound insulation structure with a breakdown strength of less than a few thousand volts. Consequently, most test codes call for high-potential testing values of twice-rated voltage plus a 1,000-v for a period of 1 min. If the equipment is originally designed to stand a slightly higher voltage than this for a longer length of time, the damage that might be done at the test voltage is minute, and sound insulation would not be harmed even after hundreds of tests. If the test value is chosen too low, the test may as well not be made, for it will give a false sense of security.

Minimizing Destructiveness By Current Limiting

When the voltage-withstand strength of equipment under test is not known or inconvenient to determine, current-limited high-voltage test equipment can be used to insure nondestructiveness of the dielectric strength test. The current limiting may either be in the form of (1) a fast-acting circuit breaker in the output of the test set (set to trip at a few milliamperes or less), or (2) a collapsing-field type high-voltage transformer that automatically lowers output voltage as load current increases.

With equipment of this type, the test voltage is lowered or removed before the insulation can

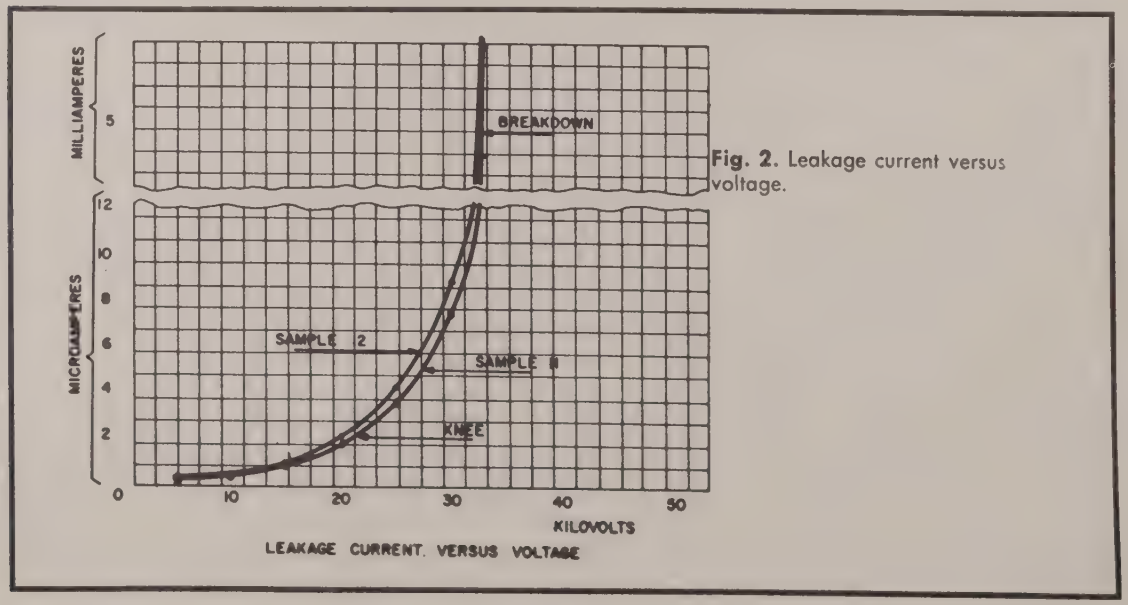


Fig. 2. Leakage current versus voltage.

rupture. Thousands of test sets of this type are in continuous use today, testing all types of consumer items without any evidence of causing equipment damage.

Internal Corona Develops Due to Voids in Insulation

Often, in running a high-potential test, internal corona develops due to voids in the insulation, at voltages far below the breakdown voltage of the insulation itself. Unfortunately, the presence of this corona won't show up with most test sets in common use.

Corona produced during testing may rapidly deteriorate the insulation; since the effect of this deterioration is cumulative, subsequent high-voltage tests are usually blamed for failure. Note, however, the production of corona actually indicates a defect (usually a void) in the insulation; thus, the insulation could not be considered sound. When corona damage is significant in the equipment being tested, a high-potential test should be made, using modern corona detection equipment that displays the presence of even minute amounts of corona. Using this type of equipment, the high-voltage test could be stopped at the point of inception of corona, thus preventing harm to the insulation.

DC High-Potential Testing Is an Important Consideration

Another very important consideration in the destructive or nondestructive aspect of high-potential tests is the relative results obtained with ac or dc. Ac testing is usually considered a go/no-go type of proposition. In other words, voltage is run up to a specified value; if the sample breaks down, it is no good; if it does not break down, it is assumed good.

Unless proper precautions are taken, there is no way of knowing how close the sample approaches the breakdown point. On the other hand, with dc testing, the procedure is somewhat different; leakage current is measured as voltage is raised. As long as current varies approximately linearily with test voltage, the equipment is in good condition. In most cases (this depends on the particular insulation materials involved) there will be a knee in the curve of voltage-vs-current, prior to breakdown. In other words, as the breakdown point is approached, the leakage current starts increasing at a higher rate; soon the avalanche current referred to above appears. On certain newer materials, this knee is almost a right-angle bend; breakdown is reached at about the same time the first sign of the knee appears. In many cases, however, the knee is gradual enough so that the change-of-slope of the current vs voltage current is apparent; if the test is stopped at that point, no harm is done and the test may be repeated almost indefinitely. Here we have a truly nondestructive test, because, regardless at what voltage deterioration starts to take place, the careful operator (in many cases) can end a test prior to any damage. Careful observation of the slope of the curve of leakage current-vs-applied voltage will yield valuable information about the adequacy, condition, and even expected life of the insulation.

Rate of Application of Voltage Will Affect Breakdown Point

The method of voltage application will have some effect on the breakdown point. Most published data indicates that the slower the application of voltage, the more apt the failure to occur at a lower value. Note that in impulse testing of high-voltage insulators and transmission line equipment, voltages many times the normal high-potential test values are used. ASTM Specification D-149, Parag. 3, says, "In general, the dielectric strength decreases with time of exposure to the electrical stress." Appendix I to that same specification says, "The more rapid the increase in voltage, the higher will be the breakdown voltage."

Typical Results Are Described

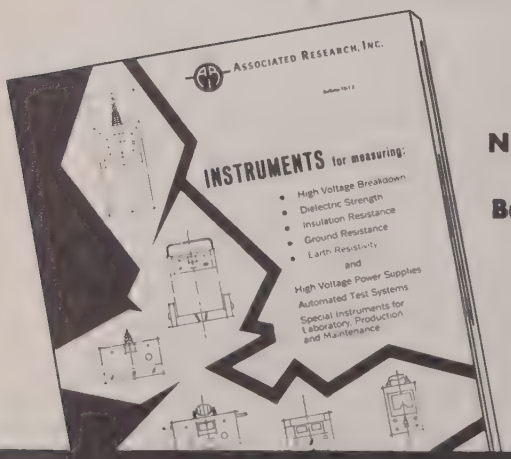
Despite the massive amount of data supporting the above explanation, additional tests were run at our firm under semicontrolled conditions (to simulate production testing rather than laboratory testing). Ac tests were run, using our model 4501 35-kv oil tester and a model 4505 35-kv materials tester. Dc tests were run using our Model 5265 15/30/45 kv dc Hypot. Various samples were tested, including transformer insulating oils, cellulose acetate film, polyethylene sheets, insulated wire, and simple subassemblies. Results of these test (three are summarized below) amply bear out this fact: properly conducted, high voltage test can be nondestructive.

Test 1: Tests were made on identical samples of transformer grade insulating oil, following the procedure in ASTM D877-49, "Test for Dielectric Strength of Insulating Oil." Fifteen samples of oil, used as a control group, were tested to determine the breakdown voltage. All fifteen broke down between 25 and 28 kv; average for the group was 26 kv. Sample No. 16 was tested by raising the voltage at 3 kv per sec up to 20 kv and rapidly dropping the voltage to zero for 100 times, at 2-min intervals. That sample was then tested to breakdown, which occurred at 28 kv; the sample finally broke down on the 88th test (at 25 kv). Sample No. 17 was tested at 22.5 kv for 150 times without failure. The test voltage was raised to 25 kv; the sample finally broke down on the 88th test (at 25 kv). Sample No. 18 was raised to 25 kv and held at that voltage for 1 min before returning to zero. This was repeated until breakdown occurred on the 21st test. Ten more samples were tested to determine the breakdown point. Breakdown in each case fell between 25 and 29 kv.

Test 2: Samples of 0.008-in. cellulose acetate tape were tested in accordance with ASTM Specification D1202-52T, "Cellulose Acetate Sheet and Film." Several control samples were tested to determine the average breakdown value (15 kv). Additional samples of the same material (taken from the same piece) were then given repetitive high-voltage tests, running up to 10,000 v at the rate of 500 v per sec, with rapid return to zero. These tests were repeated 50 times for each sample without failure. The test voltage was then raised until the samples actually broke down, which occurred between 16 and 17.5 kv for this group. Another sample of the same material was raised to 10 kv and the voltage left for 1 hr. The voltage was raised to 12.5 kv; breakdown occurred after 35 min.

Test 3: Samples of insulated cable were tested with dc. In each case, the voltage was raised to 20 kv; the leakage current was recorded. The control samples showed leakage currents between 1.5 and 2 μa at 20 kv. The voltage of sample No. 11 was increased until breakdown occurred at 32.5 kv. The voltage on sample No. 11 was increased until breakdown occurred at 32.5 kv. The voltage on sample No. 12 was raised to 25 kv and maintained for 2 hr before lowering. The cable showed no sign of damage, nor was there any measurable increase of leakage current during that period. The same sample was then tested 25 times at 20 kv, allowing suitable intervals between tests to permit complete discharge. On the 25th time, leakage current at 20 kv was still identical with the value recorded the first time. The voltage on the same sample was then raised to breakdown, which occurred at 32.5 kv. As shown in Fig. 2, the curve of leakage current-vs-voltage for sample No. 12 (which received a 2-hr test and 25 short tests) is almost identical to the curve of the control sample No. 11, which was raised to breakdown voltage on its first test trial. ■ ■

High Voltage Breakdown Testing . . A-C or D-C



NEW...

Bulletin 10-1.3

A full range of instrumentation for non-destructive breakdown tests is offered. Pages 4, 5, 6 and 7 of this catalog describe each basic series. Page 11 gives data on automated systems for dielectric strength testing. Page 3 refers to instrumentation combining dielectric strength testing with tests that are frequently made concurrently.

Our experience as one of the largest and best equipped producers of heavy duty dielectric test sets has shown the need for wide variations in the facilities to be embodied in the individual test set.

Thus, basic HYPOT® designs presented on these pages are essentially for reference. Additional facilities required for specific applications may be incorporated. Many of the useful features described are available only in HYPOT® test sets. Provisions for material and equipment testing in accord with applicable ASTM, MIL, and Federal Specifications are provided by suitable HYPOT® models.

361-2.5

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Bulletin 5-15.5

ASSOCIATED RESEARCH, Incorporated
"Electrical Testing Instruments Since 1936"
INSTRUMENT APPLICATION NOTES

A-C/D-C High-Potential Testing

HAROLD N. MILLER
Vice-president, Engineering
ASSOCIATED RESEARCH, INC.
Chicago, Illinois

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HIGH-POTENTIAL TESTING is a well-established tool for the evaluation of insulation systems. In spite of this, there is a lack of understanding regarding the equipment and test procedures.

High-potential tests are used as an aid in design, quality control, and safety evaluation, but most frequently they are made to determine compliance with specifications that require the test. Properly conducted tests will indicate the insulation level and faults such as cracks, discontinuities, thin spots or voids in the insulation, excessive moisture or dirt, possible operator hazard, corona starting voltage, and may permit a good estimate of the equipment's expected operating life.

Failure Indication. While many specifications require high-potential tests, few detail the method of testing or the indication of failure, frequently specifying only that a high-potential test shall be made (sometimes not even specifying test voltage). What constitutes failure is frequently a moot point also since, depending on the material or type of equipment, failure may be evidenced by excessive leakage current or actual insulation breakdown. In the case of the former, leakage currents of a few microamperes may be excessive with certain materials, while for others several milliamperes may be acceptable.

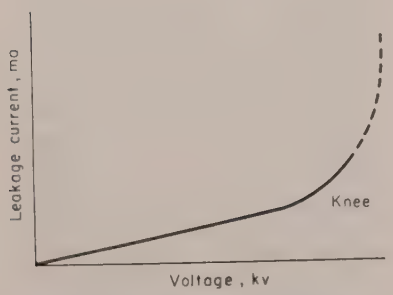


Fig. 1 — Leakage-current *vs* voltage curve obtained in high-potential test. Item being tested is acceptable if knee of curve does occur above maximum test voltage.

Determination of insulation breakdown is more obvious, as it is characterized by a destructive discharge through the insulation. Since breakdown failure actually damages the insulation, it is usually impossible to restore the test voltage to the previous value.

A-C or D-C Testing. The question of a-c *vs* d-c testing is a perennial one. Because of the earlier availability of suitable equipment, a-c testing has had a head start. Most equipment specifications have been written in terms of a-c testing, and many engineers are familiar with it, while companies have large investments in the equipment involved. In instances where d-c high-potential testing could be profitably employed, its use is deferred in favor of a-c testing.

There are many cases where a-c testing is preferable to d-c. When equipment using several insulating materials is tested, a-c stresses the insulation in proportion to electric strength, whereas d-c stresses the materials in proportion to insulation resistance. A-C testing simulates operating conditions more closely than d-c does. Many comparative test data have been accumulated on the use of a-c testing on many materials. As a GO, NO-GO production test on small items such as toasters and radios, a-c testing is properly popular.

Since an a-c high-potential test must supply the quadrature (capacitance) current as well as the leakage current, capacitance of the item being tested is of great importance. On low-capacitance items the quadrature current is small compared to the leakage current and the avalanche of current produced at breakdown becomes readily discernible. The small a-c high-potential tester has a leakage light that glows when the total current exceeds the preset value (usually between 0.3 and 3 ma), or a sensitive circuit breaker. In the case of larger equipment or with long cables, the quadrature current may be considerably larger than and masks the leakage current. Quadrature current may be so high that unreasonably large test equipment is required. For example, a 100,000 kva generator may have a quadrature current of about 3 amp at 25 kv, The test set therefore would have to have a capacity of approximately 75 kva to supply this component alone.

For many applications the use of d-c has several advantages over a-c. Direct-current tests yield more information than is obtainable with a-c tests. With d-c testing, measurement of leakage current while the high-voltage test is under way permits evaluation of the material or equipment.

When performing a high-potential test with d-c, the initial application of voltage will cause a high charging current which exponentially decays to a lower steady-state value (consisting of actual leakage current and the dielectric absorption current, Fig. 1). Since most items tested present a capacitive load which initially acts as a short circuit, the high initial inrush current is determined by the change in voltage and the circuit series resistance. Therefore, it is possible to charge even a large item with a very small d-c test set by raising the voltage slowly enough to keep initial charging current below the maximum output capabilities of the test set or by using a current-limiting series resistor. Many high-potential test sets (especially those used in high-production or automatic test equipment) can supply exceptionally high initial charging currents to shorten test time.

In many cases, the rate of change of current is more important than actual magnitude. However, comparison of leakage current with values obtained in prior tests of the same equipment will give a good indication of insulation condition. Higher leakage current is usu-

ally an indication of poorer insulation, but this is a matter difficult to evaluate in a single test. As long as the curve of leakage current *vs* voltage is of the general shape shown in Fig. 1, and as long as the knee occurs above the maximum test voltage required, the equipment being tested may be considered satisfactory.

Test Voltage Magnitude. Unfortunately, specifications are not always available to give the magnitude of test voltage, but there are guides that may be used. For consumer items, Underwriters Laboratories and others usually specify an a-c test potential of twice the operating voltage plus 1000. This figure is also generally accepted in production testing of components and subassemblies. Acceptance testing is frequently made at about 80 per cent of the factory test voltage, while maintenance testing is performed at 50 to 80 per cent of factory voltage, depending upon equipment age and the facility involved. Tests on insulation materials are generally well described by specifying agencies such as ASTM. These specifications not only describe the method of test and test voltages to use, but the test fixtures as well.

Conversion factors (the value of d-c test voltage to use when a-c test voltage is given) may range from 1:1 to as high as 4:1. A value of 1.7:1, with d-c voltage of 1.7 times a-c test voltage, is quite common.

High-Potential Test Set Size. With the current emphasis on high-potential testing, it is important that anticipated as well as present requirements be evaluated when selecting the size of a test set. As a rough guide, it is suggested that the maximum voltage range of the tester be at least 25 per cent higher than the maximum voltage anticipated. If much testing is to be conducted at lower voltages, it might be desirable to include multiple ranges in the unit. The kva rating of an a-c tester is greatly dependent upon capacitance of the item being tested. For small items such as appliances, other consumer equipment and small motors, a high-potential tester with a rating of 1 kva or lower is usually adequate. Materials testing specifications frequently require a 2-kva unit. For testing larger equipment, test-set size may be calculated once capacitance of the item to be tested is known. On larger items, the capacitance greatly exceeds the leakage current; thus, the quadrature current may be used as a basis for selection. With the normal 60-cps supply:

$$I = 377CE_T$$

and

$$KVA_H = 0.377CE_TE$$

where

I = quadrature current in ma
KVA_H = kva rating of high-potential tester
C = capacitance of unit under test in μf
E_T = test voltage in kv
E = maximum test-set voltage in kv

Or, where tests are to be made at substantially full test-set voltage:

$$KVA_H = 0.377CE^2$$

The chart in Fig. 2 shows the kva rating required to test a given load.

It is often necessary to test both large and small items. Since test-set efficiency decreases at the low end of the voltage range, a 100-kv high-potential tester is not too satisfactory for making tests at 500 or 1000 volts, nor is a unit capable of delivering 5 kva entirely satisfactory for testing equipment requiring only 5 va. The cost of the special features necessary to read both large and very small currents usually amounts to more than the price of a second small unit.

While a-c high-potential testers are generally rated by kva available at maximum voltage, d-c testers are rated by maximum voltage and current. Selection of d-c test sets is influenced primarily by maximum leakage current and charging current needed. The minimum expected value of leakage current must also be known in order to select the proper low-current range, since most d-c test sets are multi-range instruments. If the minimum acceptable insulation resistance and the required test voltages are known, expected leakage current may be calculated by using Ohm's law.

The high-potential tester chosen should have a low-current range of not more than four or five times the value of leakage current of interest. The highest current range of the tester will depend on the length of time available to charge the item under test, since the higher the maximum current rating, the faster the voltage can be raised without overloading the tester. A 2.5-ma high-potential tester is adequate for most cable and rotating machinery applications, but 5- and 10-ma ratings are also common.

Combination A-C/D-C Test Sets. Although combination high-potential testers are available, it is more satisfactory (and as economical) to have separate units. The voltage doublers and quadruplers often used in d-c test sets permit use of a transformer with an output voltage of only one-quarter to one-half that of the tester itself. In an a-c high-potential tester, a larger transformer rated at the full voltage of the test set is required. Metering and protective circuits which are effective for d-c are not best for a-c testers. Voltage-control equipment required on an a-c set is much larger than that required on d-c sets because of the larger a-c components. The combination tester usually represents a compromise with the added complication of high-voltage switching problems.

Corona. With the advent of new insulation materials and higher-altitude operation, corona has become increasingly important. This corona may be internal (within a void in the insulation), in which case the cumulative deterioration is of particular significance —especially with materials such as Mylar and TFE-fluorocarbon; or the corona may be external to the equipment being tested, originating at or around the connections or exposed high-voltage points; or, finally, the corona may be within the test set itself. Corona masks the reading of leakage current and makes evaluation of the high-potential test more difficult.

Eliminating external corona is usually relatively simple when making a test with a modern high-potential tester having special bypass circuits. The corona is offered a low-resistance path bypassing the current-metering circuit, so the instrument only measures true leakage current.

Regardless of how corona is detected, it is virtually impossible to distinguish

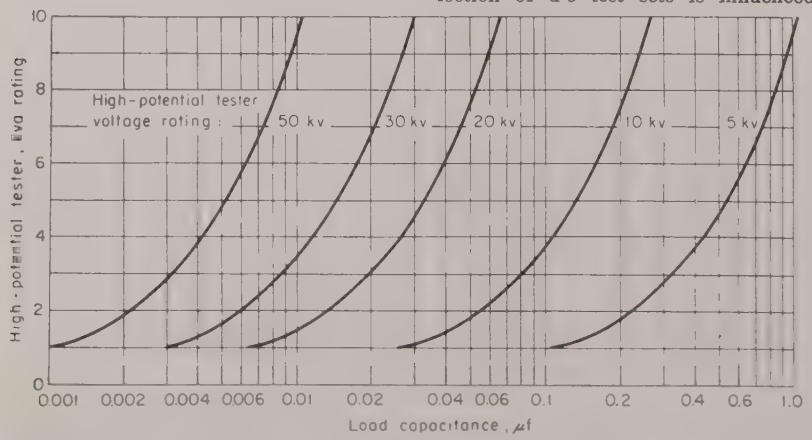
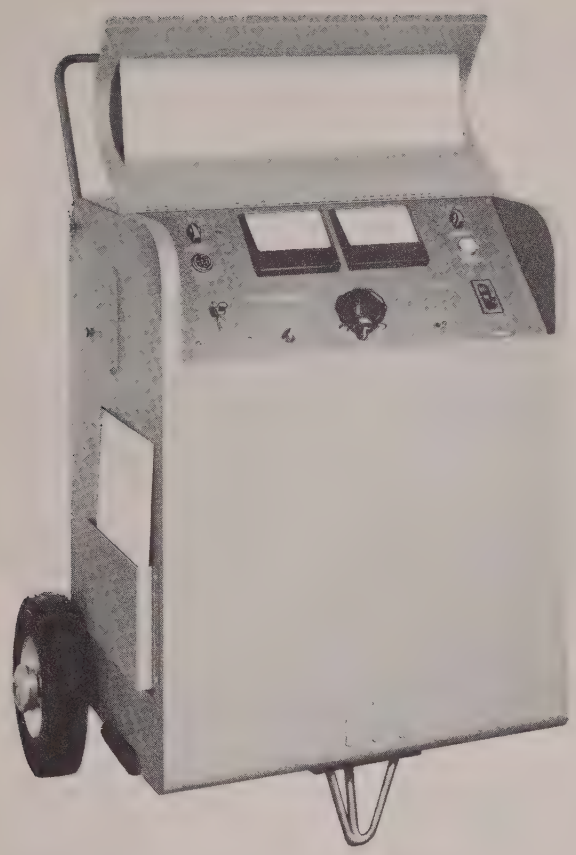


Fig. 2 — Relation of maximum capacitive load that can be tested, kva rating of high-potential tester, and maximum tester output voltage. For example: a 30-kv, 5-kva test set can test a motor with up to 0.015 μf capacitance, winding-to-frame.



Mobile D-C HYPOTS® . . to 120 KV, 10 MA

Heavy-duty mobile test sets for determining insulation leakage and dielectric strength of cables, bushings, switchgear, transformers, motors and generators . . . on the factory floor, outdoors, or in mines and quarries.

Outputs continuously variable from 0 to 45 kv and on up to 120 kv, with ratings of 2.5, 5, 10 ma, at full voltage. Operate from 115 v, a-c. High voltage receptacle may be oil filled for corona-free connection. The mobile cabinets are similar in design and dimensions to those listed for the "Mobile A-C HYPOTS®." Weights range from 285 to 450 pounds.

Standard features include: 4½" kilovoltmeter connected directly across the high voltage output; three-range 4½" microammeter electronically protected against overload; zero return interlock; connector for remote safety interlock; fast-acting magnetic circuit breaker in output to protect high voltage circuits and external load; thermal overload breaker to protect input circuits; long-life selenium high voltage rectifiers; metered return and bypass return terminals for measurement of load (leakage) or bypass (guard) currents.

Optional features include: Multiple output voltage ranges, vacuum tube microammeter with ranges as low as 2 microamperes, full scale, reversible polarity, adjustable high limit shut off for voltage and current.

corona emanating from the test equipment from that generated within the equipment being tested. While a good high-potential test set is relatively corona-free up to two-thirds or three-fourths of its maximum output voltage, sensitive corona test equipment would indicate some corona present (not visible or audible) at voltages as low as one-fourth to one-third of the rating. The corona test set consists of a specially constructed corona-free high-potential tester, a pickup device to abstract the true corona voltage from the test voltage, and a corona-detection and display section which presents the discharge on a built-in oscilloscope and indicates the exact starting voltage.

Insulation Resistance. The d-c high-potential tester is an invaluable tool in making insulation-resistance measurements at higher voltages. As in ordinary high-potential testing, the voltage is raised to the desired value, the current is allowed to stabilize, test voltage read and the insulation resistance calculated by Ohm's law.

Curves of insulation resistance *vs* voltage will yield much information to the experienced operator. Records of insulation resistance values at a specific voltage may be kept and compared from test-to-test or year-to-year.

Insulation resistance may also be measured with standard megohmmeters. These instruments give a direct reading of insulation resistance at a 500-volt, or higher, test potential. This test instrument should not be confused with a high-potential tester, since insulation resistance usually has little or no direct relationship to electric or breakdown strength. For example, an actual void in the insulation may show an exceedingly high value of insulation resistance even though it would permit breakdown at a relatively low voltage. Insulation resistance measurements with a megohmmeter are of help in determining whether the item under test is even suitable for high-potential testing. If insulation resistance is abnormally low, the material is defective and there is no need to make the high-potential test.

Instead of waiting for the current to stabilize before calculating insulation resistance, readings of voltage and current can be taken at fixed time intervals during a leakage-current *vs* time test and insulation resistance calculated for each step. A plot of insulation resistance *vs* time is known as the *absorption curve* and is often used when testing rotating machinery. In a good insulation system, this curve will rise rapidly at first because of the decaying charging current. The more pronounced the rise, the better the insulation. A relatively flat curve will indicate moist or dirty insulation.

The ratio of insulation resistance at the end of ten minutes to the resistance at the end of one minute is known as the *polarization index.* If the polarization index is less than two, it is usually an indication of excessive moisture or contamination. Values of ten or more are common when testing large motors or generators.

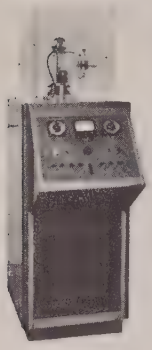
Caution should be exercised in evaluating the importance of insulation-resistance measurements. The absolute value is not critical, but relative order of magnitude or the change in value as the test progresses is significant. Factors such as temperature and humidity can have a great effect on the insulation-resistance reading.

Safety. The element of danger in high-voltage testing may be minimized when properly constructed equipment is used with care. When making d-c tests on high-capacitance equipment, such as long lengths of cable, it is important to put an external ground on the cable before disconnecting it from the high-potential tester. It is equally important to wear rubber gloves at this point because the effect of absorption currents may cause a voltage build-up on the item under test until it has been grounded for some time.

Careful study of the item under high-potential test with a clear understanding of the proper procedure and necessary precautions will result in dependable and valuable results. O O O

Headquarters for INSULATION TESTING

NEW INSTRUMENTS from Associated Research, Inc. . . . Chicago, Ill.



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Mobile HYPOTS® . . to 120 kv

Mobile high voltage test sets determine insulation breakdown in cables, bushings, transformers, motors and similar equipment. They are readily transportable, have advanced safety features and meet applicable specifications for testing elements of electronic, missile and ground support systems. Widely used by electric utilities and for industrial maintenance. Descriptive bulletin available.

Measure Insulation Resistance to FIVE MILLION Megohms

The VIBROTEST® megohmmeter is direct reading with an electronic power supply that eliminates cranking and leveling. Multi-range models combine megohm, d-c and a-c voltage measurement in compact instruments with welded steel portable case.

Model 250 VIBROTEST® Megohmmeter with 4½" scale, has ranges: 1 to 50, 10 to 500, 100 to 5,000 and 1,000 to 50,000 megohms. Price, $279.50. Catalog describes many additional models.

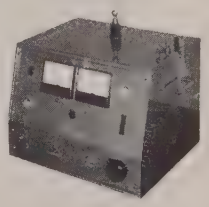
Portable HYPOTS® . . to 10 kv

Compact instruments for measurement of insulation breakdown voltage and leakage current. Outputs to 10 kv, a-c. Also, with d-c output voltage. New bulletin describes many available models.

Model 412 Portable HYPOT® has output adjutsable 0 to 1500 v, a-c. Leakage current readout light adjustable from 0.3 to 3.0 ma. Price $137.50.

Bench HYPOTS® . . to 45 kv

Semi-portable instruments measure insulation leakage current and breakdown voltage. Available with d-c output voltage to 45 kv at 25 ma, and with a-c output to 35 kv at 2 kva. Bench type welded steel cabinets have carrying handles.



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VIBROGROUND® Ohmmeters measure resistance to ground from electrical and electronic equipment. They are direct reading, self-powered from long life battery. Bulletin available, lists all models as well as instruments for measuring soil resistivity and conductance.

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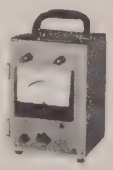
Illustrated at left, is multi-circuit analyzer for cables, components and circuits . . with printed tape readout of rejections.

Corona Testing Equipment

New instruments detect and display on oscilloscope, minute traces of corona . . whether caused by voids within the insulation or other defects. The corona may be studied visually, measured with a calibrator or trigger an alarm. A bulletin on corona testing systems, corona-free HYPOTS®, and corona detectors, is available.

Precision Ohmmeters (½ of 1%)



Direct reading resistance measurements are made with an accuracy of up to ½ of 1% . . from 0.05 ohm to 100,000 ohms. Have compenastion for battery and lead resistance, self-contained battery. Model 244 has ranges of 0-50/500/5,000/50,000 ohms. Price, $128.00 . . Model 246, ranges to 100,000 ohms, $148.00.

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Designed to your needs . . embodying these and related measurements: Continuity, Insulation Resistance, High Voltage Breakdown, Leakage Current, Capacitance and Inductance Bridge. Also, modification of standard instruments will be made as required to meet your applications. When writing, give complete details of your requirement.

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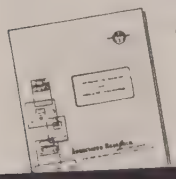
Available as general purpose units or with facilities for specific applications. HYPOT® D-C power supplies are widely used in test and development of capacitors, cables, klystrons and other high voltage devices. Output voltages to 250 kv with full load ratings to 50 ma, are offered. Our engineering department will supply full data on models suitable for your requirements.

NEW . . . Insulation Testing Manual C-61



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Bulletin 10-15.1

Insulation

High Potential Dielectric Testing

Editor's Note: The following are excerpts from the transcript of a technical seminar held on the West Coast to clarify some of the confusion and disagreement regarding dielectric strength testing. Members of the panel were: J. P. Dallas of Hughes Tool Co., Fellow of AIEE, and chairman of the Subcommittee on Dielectric Testing of Aircraft Equipment; H. N. Miller, vice president engineering, of Associated Research, Inc., one of the largest manufacturers of high potential dielectric strength testing equipment, member of AIEE, IRE, and ASTM; and C. L. Sidway of the Southern California Edison Co., member of AIEE and expert on the dielectric testing of large rotating machinery. The moderator was M. A. Brenner of Brenner-Fiedler and Associates, Inc.

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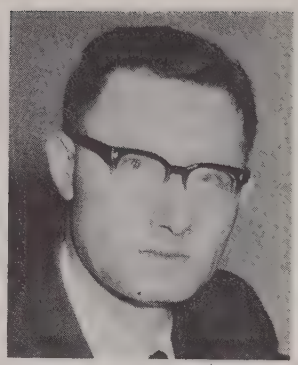
Associated Research, Inc. . . . Chicago, U.S.A.

J. P. Dallas

C. L. Sidway



H. N. Miller

M. A. Brenner

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Brenner: What do we mean by dielectric strength?

Miller: Dielectric strength is defined as the voltage rating at which electrical failure or breakdown occurs. It is commonly expressed in volts per mil, obtained by dividing the breakdown voltage by the thickness of insulation. The value is influenced by the method of application of voltage, frequency, wave shape, temperature, and surrounding medium.

Brenner: What about leakage current, test current, circuit current, and so forth?

Sidway: When you apply a direct potential to an insulated structure, the initial surge of current is known as the charging current. As time goes on the current drops exponentially, and another effect known as absorption current becomes predominant. If the potential is left on long enough the current eventually reduces to a steady value, known as the conduction current. In insulation testing, it is the conduction current in which we are primarily interested. When testing with alternating potential the charging component is extremely large compared to all the other components, so leakage current is relatively minor.

Brenner: Is breakdown an excessive steady current, arcing, or short circuit?

Sidway: Breakdown is usually described as a destructive discharge through the insulation. It is characterized by a disproportionately large change in the testing current; in other words, an avalanche. After breakdown failure occurs you usually cannot restore the voltage. For example, while slowly increasing the voltage you may find current increasing quite rapidly at a certain point, but you may have only reached the point where some of the voids in the insulation material have become ionized. If that is the case you can back down on the voltage and return to the same place as often as you wish. In a true breakdown you will not be able to raise the voltage to that point again.

Dallas: Insulation breakdown is also defined as a rupture of the insulation which results in the increase of leakage current at the specified test voltage.

Brenner: What is the relationship between insulation resistance testing and high potential testing?

Dallas: We use insulation resistance tests to tell us if insulation is contaminated or to discover things that are wrong with insulation that we can correct. Low insulation resistance may indicate what equipment is wet, dirty, deteriorated, etc. Though this would not necessarily result in breakdown it could result in short life, since current flow through insulation causes an electrolytic action which probably would hasten the ultimate failure. The minimum acceptable insulation resistance has been pretty well standardized as one megohm.

Sidway: The measurement of insulation resistance is affected by the voltage as well as the length of test time. The insulation resistance at the end of one minute, divided by the insulation resistance at the end of ten minutes is known as the polarization index. When the index is less than one half, you can be pretty sure that the insulation is dirty or contaminated, or otherwise defective. Generally, the

higher the polarization index the better the insulation. Temperature of the test also has a very pronounced effect on the measurement.

Miller: Insulation resistance testing is frequently used as a production line sorting test. For example, if 499 out of 500 amplifiers, toasters, or electric irons have a comparatively high insulation resistance while the 500th one has a low value, we throw out the 500th one because we know it is worse than the other 499. There also is a slight relationship between insulation resistance testing and breakdown strength testing (hi-pot testing), in that normally in a given piece of equipment the higher insulation resistance value indicates the ability to withstand higher voltages before excessive leakage current is drawn.

Dallas: These are things that are practically non-existent in any of the insulations that we have to use on aircraft and missile equipment. If you took samples of "Teflon," mica, and polyethylene materials and tried to compare values on the basis of insulation resistance you wouldn't get anywhere, especially since we are dealing with small areas of material that are harder to evaluate. These materials can yield figures of insulation resistance in the neighborhood of 100 to 200 megohms or even much higher.

Brenner: Is insulation resistance or high potential testing better for predicting equipment life, or do they complement each other?

Miller: In general, in tests made on high-production, low-priced types of equipment there is some correlation between insulation resistance and high potential testing. The hi-pot test usually called for is not a real breakdown test but merely the application of a relatively low (500 to 2000 volts) voltage to the equipment, and in one way or another you measure leakage current—whether by means of a leakage light, circuit breaker, or microammeter. You are actually interpreting the hi-pot test in terms of insulation resistance, because naturally, the higher the leakage current the lower the insulation resistance. The equipment specifications will frequently tie you down by calling for one or the other of the tests.

Brenner: For quality control purposes can you get better results by first running an insulation resistance test, then a hi-pot test, then another insulation resistance test, and then comparing the values of the two insulation resistance tests?

Sidway: In testing large machinery we always make an insulation resistance test first, simply to determine if the system is suitable for applying a high potential. The only way we can find out if the system has a specific dielectric strength is to apply the high voltage. If there is no breakdown we are reassured that barring accident or change in operating conditions, the equipment will run until the next time we test it.

Dallas: When a switch is opened or closed the transient voltages developed rise to an exceedingly high value compared to the circuit voltage, and it is one of the main reasons for making hi-pot tests. The purpose of the high potential test is to detect flaws in the insulation, and since most insulations of even a few thousandths of an inch thickness will withstand several thousand volts without being unduly stressed, a test voltage of around a thousand volts or so will not harm healthy insulation.

Sidway: If you make an insulation resistance measurement and find that it is exceedingly low you certainly should not try to apply a high potential test. On the other hand, if the insulation resistance is very high it still does not give any assurance that the structure will pass a high potential test. Since leakage current flows pretty generally over the surface of the insulation as well as through the insulation itself, the effect of a small pinhole which could cause a voltage breakdown may be rather slight in the measurement of the insulation resistance. We have found after making numerous tests that the difference in insulation resistance before and after hi-potting is not much of a criterion.

Question from the Floor: Can you use a hi-pot test to make an insulation resistance test?

Miller: If you are making a high potential test using d-c you can read the leakage current directly on the milliammeter, and at any given instant you can calculate the insulation resistance by using Ohm's Law: $R = \frac{E}{I}$.

Most insulation resistance tests are specified at 500 volts, so all you have to do is raise your voltage to that value and divide the 500 volts by the leakage current to get your insulation resistance. Then of course you can continue raising the voltage until you break the insulation down.

Sidway: The value you get in measuring insulation resistance depends on the test voltage. In one example the insulation resistance measured at 10,000 volts was 3800 megohms; at 15,000 volts it was 2700 megohms; at 20,000 volts it dropped to 2000 megohms; and at 25,000 volts it was down to 1500 megohms. It is quite feasible to calculate insulation resistance while you are making a d-c hi-pot test, and if you do it properly you can get almost any value you choose.

Dallas: For about 75 years the electrical industry has used the figure of one megohm for satisfactory insulation resistance. It is pretty much a rule of thumb. The reason some of the missile people call for high impedances is partially due to inexperience or as a result of less than optimum design.

Brenner: The commonly accepted test voltage in a-c high potential test is twice rated voltage plus 1000 volts. Is this still valid?

Dallas: In the early days of electrical design it was decided that a reasonable surge for switching transients was about 1000 volts. Then if you added twice the line voltage you had a good basis for a high potential test. I believe that is as true today as it was 75 years ago.

Sidway: As soon as a machine is put into service the insulation starts to degrade because of the effects of temperature, time, moisture, vibration, etc. The machines must still withstand the effect of surges, lightning and other high potentials. I concur that the figure is still valid today.

Brenner: In the missile field—especially where we operate with very low voltages of 28 volts d-c, using small components, fine wire, etc.—won't

this application of twice rated voltage plus one thousand cause damage to the equipment? Shouldn't we therefore lower the value?

Dallas: It is a recommendation of the AIEE subcommittee on Aircraft Equipment, Electrical Insulation, that not less than 1500 volts or 1000 volts plus twice line voltage be applied to all equipment. This is to find flaws in the equipment and has nothing to do with wire or component sizes. To put a voltage across a .003″ air gap takes about 1200 volts, but the 1200 volts won't stress .003″ thick "Mylar" at all. It would take 3000 or 4000 volts per .001″. So whether the equipment operates on 2 volts or 1000 volts, the problem remains of finding the flaws in the primary insulation and that requires a sufficiently high test voltage.

Brenner: Can you determine anything from a high potential test using only 100 or 200 volts?

Dallas: You can learn absolutely nothing from a high potential test if the voltage isn't high enough to show flaws in the minimum thickness of insulation.

Brenner: Can we conduct a high potential test that is not damaging but will still yield some valuable information? In other words, does a high potential test have to be destructive to achieve its purpose?

Sidway: The purpose of the high potential test is to find faults in the insulation. The simplest test is the breakdown test, since it gives you the most straightforward answer. In a design test you want to find what value of voltage the insulation system will withstand, so you test it until it fails; then you know it will withstand a little less than the voltage you have applied. It has been our experience that test voltages of about 70 or 75% of the actual breakdown value will not even begin to injure the material during the test. Therefore, the design value of the insulation strength should be well above the value you expect to use in production testing. The length of time of application of the voltage is very important because of an insulation characteristic we will call voltage endurance. It is somewhat akin to the relationship of fatigue tests on metal and their tensile strength. The tensile strength is always higher than fatigue strength, so in our insulation system the short time strength is always higher than the long time strength. Results of many tests indicate that the rate of degradation during d-c high potential testing is considerably less than in a-c tests.

Brenner: If you are conducting an a-c test on a production line and one item has considerably more leakage current than other similar items, would you consider that a defective part or must you actually have a rupture or avalanche of current?

Dallas: It would depend entirely on the values found. The fact that there is a difference in the area below one megohm would be of special significance. You can just breathe on some surfaces, however, and drop the insulation resistance from 100 megohms to 20 megohms. In general, the high values are unstable; so if there is a difference above one megohm, don't pay any attention to it.

Sidway: I concur with Mr. Dallas that a change is significant, although I don't think the values you get are of any importance. If you are running tests on identical parts under controlled conditions and suddenly find a part that is either very high or very low, you know there is something different and you better find out why.

Brenner: If an a-c test is specified, can a d-c test also be used? If it can be used, how do we determine the d-c equivalent of the specified a-c voltage?

Dallas: For aircraft and missile equipment the d-c voltage should probably be about 1.7 x rms voltage. There is no fixed rule to apply, however, and you can find values ranging from 1.4 x rms to 2.3 x rms voltage. In our laboratory we usually use the value of 1.6 x rms voltage.

Sidway: In general, when we talk about a double voltage plus 1000 volts test we are referring to the one minute hold test. In other words, the voltage is brought up to the predetermined value and held for one minute. If you compare the d-c breakdown voltage to the one minute hold value, or compare it to rapid rise value, you will get a different ratio. The d-c test will not stress the material in the same way that the a-c does. Since most materials are not entirely homogeneous you have several dielectrics in series. With a-c, the voltage is divided across the structure in proportion to the dielectric constant of the material; while with d-c, the voltage is divided in proportion to the resistance of the material. The various sections of the material are therefore stressed differently with d-c than with a-c, since the dielectric constant does not necessarily correlate with the insulation resistance. Experience shows that imperfections, such as an actual air path, hole, or crack, will yield similar results with the 1.4 ratio between d-c and a-c. Cable manufacturers' specifications usually call for a ratio of 3 to 1, however. We have found over the years that using a direct voltage of 1.8 x a-c value has given us good results. The generally accepted rule of thumb, however, is that you should use a value of 1.6 to 1.7 times the prescribed a-c voltage.

Miller: While I agree fully with Mr. Sidway that the 1.6 to 1.7 times the a-c value is a logical choice, some specifications call for voltages of 1.1 x rms value, which is about the lowest correlation you might come across. An often specified value of 1.6 x a-c voltage for new equipment frequently is dropped to 1.1 x a-c value for older machines.

Dallas: Equipment which passes a d-c test may subsequently fail with an a-c test, since with a-c you are causing electrostatic motion of twice the applied frequency on any thin insulation sections which can move. This causes a very high stress which you don't get when using d-c. Although we frequently use d-c in aircraft missile testing, especially in large cable where it is much more convenient, we also use it with the full recognition that we have to use a higher voltage than the figures mentioned here.

Sidway: I might add that in a-c testing there is also a dielectric heating effect that in itself may lead to breakdown. A cyst or air inclusion in the insulation system may also be more readily found with an a-c breakdown test, since the distribution of voltage may cause internal corona in the void.

Brenner: Why would we want to use

d-c rather than a-c, which is the relatively established standard for high potential testing?

Miller: We recommend d-c testing wherever possible because it gives more of a qualitative rather than a go-no-go method of indication. With a-c testing you run the voltage up to a prescribed value and equipment either passes or doesn't pass the test. Failure is usually indicated by means of a circuit breaker, neon light, or any of the many other ways you can indicate leakage current or breakdown current. With the d-c test, as you gradually raise the voltage, you meter the leakage current and as long as the leakage current is climbing roughly at the same rate as the voltage, you know that the insulation is holding up. In many cases you can anticipate breakdown by observing the sudden increase in the slope of the current vs. voltage curve (called a knee). By stopping the test voltage short of the avalanche current that occurs with breakdown you can avoid damaging the equipment, but still get a good indication of the voltage at which breakdown will occur. Furthermore, with d-c testing, since you are metering the current, you can determine the leakage at any particular voltage; while with a-c testing the only indication you have is when the leakage exceeds the preset amount that triggers the leakage alarm.

Dallas: If you have a defect in the insulation, there is no reason to worry about destructiveness of the high potential test designed to detect flaws. Even if you could approach the flaw and stop you wouldn't actually want to stop, so I don't know why people testing aircraft equipment would want a so-called non-destructive test. As a matter of fact, when you are looking for a fault in the equipment you want to burn it in so you can find the exact spot where the insulation failed; therefore, a go-no-go test is exactly what you want.

Miller: The equipment being tested is the prime factor. The manufacturers of washing machines, radios, etc., wouldn't concur with you. I'm sure Mr. Sidway wouldn't want to destroy one of his 50,000 kva generators because of a potential flaw. The matter of being able to approach the breakdown point without destroying equipment leaves it up to the test engineer to determine the most appropriate time for taking the equipment out of service for repairs.

Sidway: In plotting leakage current against voltage you have to be careful, because you can get a false indication or a false interpretation of the knee in the curve. In one test we ran we suddenly got a knee at about 28,000 volts, and further investigation indicated the rapid rise of leakage current was due to corona from the test lead. As soon as the lead was replaced with a heavy shielded wire we were able to run up to 40,000 volts. In other cases where machines suddenly broke down without any sign of the knee, we found the nature of the fault was frequently a hole in the insulation. The voltage vs. current curve was smooth until the corona voltage of the hole was reached, then the sudden ionization of the air gave an immediate breakdown. In other words, you can sometimes predetermine the point at which failure will occur, but not always.

Dallas: With some of the newer insulations, that "not always" can be reworded as "very seldom." In the missile field we usually get breakdowns simultaneously with any large increase of current flow, whether it be a-c or d-c. It is almost impossible to detect breakdown just before it occurs.

Brenner: What is the principal advantage of using direct current?

Miller: In addition to the technical advantages we previously mentioned, there are sound economic reasons. I can give you a few examples to pinpoint this. On smaller equipment, that is, around 1000 to 5000 volts, d-c test equipment is a little more expensive than a-c equipment, primarily because of the more complicated metering circuits usually included. As we increase the voltage the cost of the a-c equipment goes up much faster than the d-c equipment, so that by the time we reach the 30,000 volt range the a-c equipment gets more expensive than d-c. By the time we get to about 100,000 volts or so, a-c equipment costs several times that of d-c and weighs several times as much. The a-c machine has to supply the capacitance current which gets to be considerable in the large units, while the d-c machine has to supply only the leakage current, with a little left over for stray currents.

Brenner: What are the differences in technique between a-c and d-c testing? How would you perform the test? Is the indication of failure the same in both cases?

Miller: Here again the type of equipment under consideration dictates the answer. The bulk of the miscellaneous low priced equipment such as household appliances, general consumer goods, etc., is almost universally tested with a-c; that is, low voltage a-c testing with a preset leakage light setting that will indicate leakage of more than ½ milliamp. With equipment that has higher capacitance, the leakage light setting is arbitrarily raised to a point where it will not glow for good units but will glow for poor units. The test voltage usually required by Underwriters or NEMA is twice rated voltage plus 1000 volts. Voltage is momentarily applied between live and grounded sections of the appliance. If the leakage light glows the unit is thrown aside for repair, and if it doesn't glow the unit is good and is passed. That's the way it is done in one field. Where specifications such as those set up by ASTM are required, a more rigorous procedure is followed. ASTM doesn't seem to recognize d-c testing, so any reference to an ASTM specification automatically means a-c. ASTM specs are also go-no-go type tests. In the rate-of-rise test, the voltage is raised at a preset speed which may vary from 500 volts to about 3000 volts a second, depending upon the material and specification. The test is made by raising the voltage either to a predetermined value or until the specimen breaks down. In the step-by-step method the voltage is raised in discrete steps, each value being held for a fixed interval of anywhere from a few seconds up to a minute or more, depending upon the specification. Here again the voltage is raised either to the predetermined value or until the specimen breaks down. Another type of a-c test is in the nature of

an endurance test where the voltage is held at a fixed value for an interval from a minute in some applications to a day in others. The voltage is then raised by fixed amounts and the test continued. In d-c testing the voltage is also raised by discrete amounts. At each step, sufficient length of time is allowed for the leakage current to settle down and then the voltage and the current are read and plotted. The voltage is raised up to the limits set by the specification or manufacturer or until it is anticipated that material is about to break down or even until it actually does break down, depending upon the purpose of the test. A second but not quite so common test is that of applying a preset voltage and if the equipment shows a leakage current of less than the predetermined value, the equipment is accepted; while if it is higher than that value, it is not accepted. There are about as many detailed methods of testing as there are manufacturers and testing agencies.

Brenner: What is the effect of sudden vs. gradual application of voltage?

Sidway: The rate of application affects the value you get. Most of the standards for machine testing call for application of twice rated voltage plus 1000 volts for one minute. Normally you would bring the voltage up at the rate of about 1000 to 3000 volts a minute to at least 60% of the final voltage, then raise it as quickly as you can to the final voltage. The important thing to remember is that most of the destructiveness of an a-c test occurs after the voltage has reached 70 to 75% of the breakdown strength. All the other methods Mr. Miller mentioned are used in design work or development work in developing these voltage endurance tests. When the voltage is applied to a specimen in a few microseconds we have what is called an impulse test. The breakdown strength in that type of test is quite high. As the length of time of application increases, the breakdown strength lowers.

Dallas: It is usually desirable to apply the test voltage slowly to the extent that an indication of breakdown will be an immediate signal to the operator to reduce the test voltage. The test voltage may also be applied and removed instantly, although this is a rather controversial subject. We've never been able to find evidence of any surge appearing across the equipment if we applied the voltage from the source directly to the equipment.

Miller: We have two objections to applying the high voltage suddenly. First is that of operator safety, since many times unskilled help handle the high potential test leads. This can often be adequately safeguarded so that it becomes a minor factor. The second objection is that of potential damage to the test equipment itself. The equipment being tested usually is slightly capacitive, so that at the initial application of high voltage it represents a short circuit. In the instant prior to making contact between the high potential lead and the subject, a large arc can be drawn, depending of course upon the speed of application of the test lead, the preset voltage, and the current capabilities of the machine. This arc sends out a strong RF surge through the test equipment, and a considerable amount of research was expended to develop adequate means of protecting the meter diodes and other sections. This RF surge usually results in a much higher voltage than that of the test being run. In addition, the high frequency often can burn out parts of the equipment where a 60 cycle surge will not have any effect.

Brenner: What about the effect of successive applications of high voltage? What is the effect on the output failure point of the specimen when several hi-pot tests are made in the course of its manufacture, inspection, and maintenance? If there is an effect, is there any difference in using a-c or d-c?

Dallas: Since we are extremely weight conscious in the missile field, we have to design equipment using the absolute minimum insulation to do the job. If you plot the length of time the material will withstand a given voltage against the voltage, you will find that the breakdown time increases rapidly with a decrease in voltage. In fact, when you get beyond the one hour breakdown point, a very small percent of decrease in test voltage will increase the life of the insulation a very long time. We therefore pick insulation that can withstand 1500 volts for an hour, so we are able to apply a large number of tests at that voltage without seriously deteriorating the insulation in the least during the test process. For example, 10 one minute tests will reduce the life of the insulation a very small amount. The AIEE test code which calls for a 1500 volt high potential test also calls for a 20% reduction in the high potential test voltage on repeated tests, or for service and maintenance tests. Because of the shape of the withstand time vs. voltage curve, if you go beyond the one hour point you actually can withstand hundreds of hours of testing at a 20% reduction of voltage. That means the number of re-tests that can be conducted is almost unlimited.

Sidway: I agree with Mr. Dallas but further point out that equipment manufacturers take this into account. For example, during the manufacture of a machine the wound coils are given a one minute, 60 cycle test at 135% of the final test voltage (double operating voltage plus one thousand volts). After the coils are placed in the slots they are again tested by rapidly raising the voltage to the test value and reducing it quickly. This test is made at 126%. Then, after the core and connections are taped and the winding is brought out, it will be given another rapid rise test of 116% of the double plus a thousand volts. When the winding is finally completed and reaches the test floor, it is given a one minute test at the double plus 1000 voltage. So you see in the fabrication of ordinary power equipment there is a degrading of test voltages from the time the coils are made until we make the final test. Insulation systems are so designed that none of these tests encroach on the integrity of the insulation. We have applied the one minute test repeatedly, hundreds of times, without any measurable change of quality of insulation.

Brenner: Is there anything that specifies decreasing the voltage rating in successive tests to prevent damage to insulation?

Dallas: We believe a manufacturer should do his testing at a voltage higher than the 1500 volts recommended by the aircraft industry by an amount sufficient to take care of the differences in tolerances between the meters in the manufacturers' test equipment and the customers' test equipment, line voltage surges, etc. He should add at least 15% to the test voltages. In other words, by having the manufacturer test the equipment at 1800 to 2000 volts while it is going through assembly the customer can safely apply 1500 volts test.

Brenner: Another subject tied in with testing is the effect of time on the application of voltage. In other words, why should you apply the voltage for one minute rather than one second . . . or even an hour?

Sidway: The voltage endurance periods of insulation vary with the material. You must first establish a knowledge of the dielectric properties of the material you're working with. Once you know the endurance characteristics which tell you how the dielectric stress varies as a function of time, you are in a position to fix the test values. Your system in the first place must be designed to have adequate strength; then if you test at 75% of this maximum strength, repetitive testing will not cause any damage. In other words, fears of making tests in fairly well designed systems are groundless. You cannot build a mechanically sound insulation system in which insulation is so thin that you can use a test voltage of less than 1500 volts with any assurance. Many other things hurt the system more.

Brenner: When making an endurance test, do you get the same effect if you apply the 1500 volt test potential for one minute 10 times as you would if you applied the voltage one time for 10 minutes?

Sidway: There are three main causes of insulation breakdown. Failure may occur if the current flowing through the insulation is so high the dielectric losses heat the material. Another type of failure is caused by internal ionization. The third type of failure is caused by actual electronic disintegration, as in the case of impulse testing. Generally, thermal failure occurs when the copper is run hot, which in turn heats the insulation. It is seldom caused by leakage current heating the insulation. Most of the failures we have to deal with are caused by ionic disintegration, and there it is possible to have accumulative injury if the test voltages are high enough. However, we have stressed that you should do your testing at voltages well below the predetermined ultimate strength so you will not get into the thermal or ionic disintegration range. When that is the case, it doesn't make any difference whether you apply a one minute test with rest periods 15 times or apply the same test for 15 minutes without rest periods. It is only when you are working with a value of leakage current sufficient to cause heat that cannot be radiated that the rest period becomes sensible. In many equipments we have made repetitive tests with the rest periods and have made other tests leaving the voltage on the machine for weeks at a time, and have found no changes. It is necessary to understand the area you are working in and what the nature of the destruction is, and then you can judge whether repetition is going to give you accumulative trouble.

Brenner: What is corona? What is its effect? And why do you have to worry about it when you are testing?

Sidway: There are at least two kinds of corona effects. First is the superficial corona we get due to the dielectric stresses on the surface of the equipment being tested. There, you often can see long streamers or other visible display. While this external corona does no harm, it plays havoc with any current measurements you are trying to make, because the corona currents are usually very high. The other type of corona that we do have to worry about is the corona that forms within the equipment. This corona can disintegrate insulation and exhibits an accumulative effect. Corona can be present at surprisingly low voltages. You can have serious corona problems at 4000 volts, and I've known cases of corona trouble in motors operating as low as 480 volts. Some materials are much more susceptible to corona than others. "Mylar" film in some forms is particularly sensitive.

Dallas: Corona has a strong effect on missile equipment. You can sometimes lose 20% of the effectiveness of some insulating materials after a five second exposure to corona. Essentially, corona is ionization of the air due to the high voltage, and when the air disassociates you get a bombardment of the insulation material. This doesn't affect mica too much although it will eventually erode it, but it erodes "Teflon" and "Mylar" materials very rapidly. You can get serious destruction of insulation due to field concentrations even in those cases where we can't measure the presence of corona by orthodox means.

Sidway: There is a definition of corona that describes it as a luminous discharge due to ionization of the gas around the conductor which exists when the voltage range exceeds a certain critical level. This level is the corona starting voltage and it becomes lower and lower as the atmospheric pressure decreases, so that a machine that is well designed at ground level may not work at all at higher elevations.

Brenner: In specifying high potential tests it is important to indicate the voltage, the rate of rise of that voltage, how long the voltage should be applied, and most important, what constitutes failure. Regarding failure, is there a maximum amount of allowable leakage current, or should you wait until the circuit breaker pops, should you look for arcing, or just what determines whether or not the product is acceptable?

Dallas: In testing a specific item I think either a definite leakage value or circuit breaker setting should be specified.

Sidway: The frequency of the test voltage should also be specified, since a test made at 60 cycles will give you a higher breakdown value than one made at one kilocycle. We only consider failures that are real breakdowns; that is, where we get a very high change in current flow and where we cannot raise the voltage again to the previous value. The circuit breaker should be set high enough so you actually puncture the insulation before the breaker goes.

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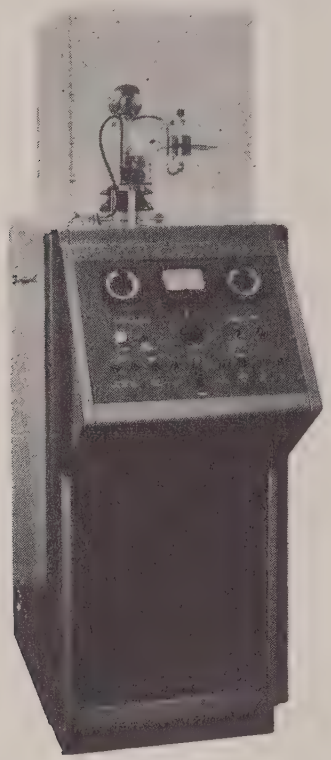

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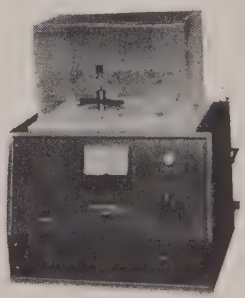

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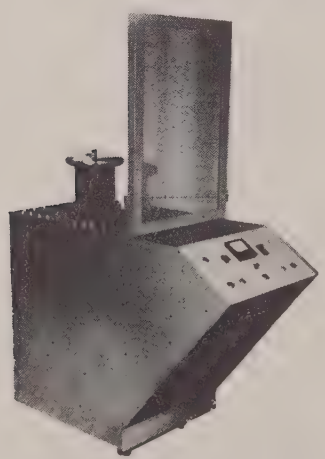

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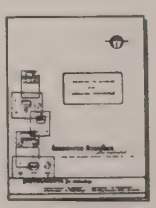

New Manual on Testing Insulating Materials

Pages of current data on methods and equipment for insulation testing. Write for Manual C-61.

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461-2.5

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Bulletin 10-15.2

The Testing Challenge

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In recent years there has been a great increase in emphasis on the testing of insulation. This greater awareness of the importance of testing has been brought about by operating conditions closer to the limits of capability of the insulations used. Miniaturization, higher altitude operation, and higher operating voltages, as well as the increased importance of reliability, make the job of insulation more difficult. As the limits of older insulations are reached and even exceeded, newer insulations must be developed to meet the newer demands. Testing plays a large part both in determining the limits of capabilities of the present insulation materials as well as helping in the development of new materials.

Author Harold N. Miller is vice president and chief engineer of Associated Research, Inc., one of the largest manufacturers of high potential dielectric strength testing equipment. He is a graduate of Massachusetts Institute of Technology, Registered Professional Engineer (State of Illinois); and member of AIEE, ASTM, and IRE. He holds several patents in the audio and automation fields and is the author of many papers about non-destructive high voltage testing and related subjects. He developed quality control and testing procedures for inspection of electronic equipment for the Signal Corps and Air Corps during World War II. During the past 15 years he has been chief engineer and consultant in the fields of design, test, and manufacturing of components, electronic equipment, and test equipment.

Necessity for Tests

However, testing for development purposes is only part of the picture. Tests are necessary in each major step of the transition from raw material to the finished product. Tests are performed in the development of the raw insulation material; further tests are performed after the insulation has been fabricated; and tests are performed on the components or assemblies that use the insulation. Final inspection tests are made on the completed equipment using the insulation, and acceptance tests are made by the purchasing agency. Maintenance tests are made during the life of the equipment and tests are made after repairs of damaged or worn equipment. Tests are made to determine compliance with specifications, and tests are made to attempt to anticipate future life of the equipment. Tests are made for safety of personnel using or coming in contact with equipment, and tests are made to determine the safety of the equipment itself.

Testing of insulation takes many forms, almost as many as there are reasons for testing. The more common tests are the mechanical, physical, or chemical tests to determine the strength, size, durability, compatability, resistance to the elements or contaminants, machinability, moldability, color, or smell.

Less familiar but equally important are the electrical tests. These tests include high potential breakdown or dielectric strength test, measurement of insulation resistance, resistivity, arc resistance tests, corona tests, and measurement of dissipation factor, power factor, and dielectric constant.

Since the importance or even the necessity for each of these tests depends on the application, it is seldom necessary to perform more than a few in any given case. To set up a logical testing program it is first necessary to determine what information is being sought, then what measurement or measurements will yield that information. The testing procedure must then be decided upon and an actual test or measurement then performed. Correlation between the test results and the sought-for information forms the last (in many cases one of the most difficult) step of the sequence.

Since one of the main uses for an insulating material is to insulate, the most common tests are those that determine how good an insulation the material is. Depending on the application, the answer may be given by determination of the breakdown strength, by the insulation resistance value, by the resistance to corona (or in the case of an assembly, the absence of corona during a high voltage test), by the resistance to tracking under arcing conditions, etc. In development work or in testing basic insulation materials, measurements yielding the absolute values are important for proper evaluation and for comparison with other materials or other samples of the same material. However, in the usual application, especially where the insulation is part of an assembly or fabrication, the value of breakdown voltage or insulation resistance is not important as long as it is sufficiently high. Determining the acceptable minimum value of breakdown voltage, insulation resistance, or corona starting voltage is, in many cases, the most difficult part of the program. This is the problem of correlation of test data (breakdown strength or other measurement) and wanted information (satisfactory insulation).

High Potential Test

One of the most important and most frequently misunderstood tests is the dielectric strength, or as it is commonly known, the high potential test. In its simplest form the high

voltage is applied between mutually insulated circuits of an assembly or across opposing faces of an insulating material. If the insulation breaks down it is bad, if it does not break down it is good. Many questions arise. Should the voltage be a-c or d-c? Should it be applied abruptly or gradually? What should be the maximum test voltage? If the voltage should be gradually applied what should the rate of rise be? How long should the maximum voltage be held? At the conclusion of the test should the voltage be abruptly shut off or should it be gradually returned to zero? What is meant by "breakdown"? Should breakdown be the criteria of failure or should excessive leakage current be questioned?

Up to about 10 years ago, almost all dielectric strength testing was done with a-c. The commonly accepted test value was taken as twice the operating voltage plus 1000 volts (rms) for most equipment. It was considered that this over-voltage test would show up materials that would be apt to break down under normal usage. The voltage usually was applied abruptly if the test value was in the neighborhood of only a few thousand volts and gradually raised or raised in discrete steps if considerably higher voltages were being used. If the insulation did not break down under the application of specified voltage, the equipment was considered acceptable. Since electrical breakdown is usually defined as a disruptive (or avalanche) current at given voltage, the start of visible arcing or the operation of the test equipment circuit breaker was used as a failure indication.

Since the heavy current avalanche at breakdown could do serious damage to the equipment, an attempt was made to determine breakdown with a little less brute force, i.e., "non-destructive" high potential testing. To meet this requirement, collapsing field high voltage transformers were (and are still being) used. With this type of high voltage transformer, the output voltage dropped when excessive current was drawn and breakdown could be determined by the sudden drop in the reading of the voltmeter placed in the output circuit. A more sophisticated approach was the use of neon lamps in the return line of the high voltage circuit. By means of a variable shunt across the neon lamp it could be set to fire at almost any desired value of leakage current. The use of neon lamps in conjunction with the collapsing field high voltage transformer give rise to small, safe high voltage test equipment suitable for use by semi-skilled or unskilled personnel for production testing of small electrical items such as toasters, radios, refrigerators, small motors, etc. The neon lamp acts as a go-no/go gauge ideal for the requirement.

Because of the limited output, this equipment is unsuitable when testing equipments drawing more than five or ten milliamperes, or with voltages above 10 kv. The poor wave shape of the output voltage also makes it undesirable in materials testing when precise measurements of breakdown voltage must be made. A fast acting magnetic circuit breaker in the high voltage circuit of a conventional test set overcomes some of these difficulties and permits limited current output with good wave shape at very high voltages.

Since an a-c test set must furnish the quadrature current due to electrical capacitance of the item under test, the size of the equipment required gets rather prohibitive when testing large items such as generating plants, large transformers, long cables, etc. In fact, with some large generators the several amperes of quadrature current necessary would require the test set to have an output of upwards of 50 to 75 kva at normal test voltages.

Since actual breakdown is the criteria of acceptability, it is rather difficult to set forth specific maximum leakage current limits. What may be an avalanche of current in some equipment, is a mere trickle for others. Fortunately in equipment having relatively low electrical capacitance (which includes most consumer type items as well as reasonably sized insulation material samples), there is such a large difference between the normal current of good material and the current flowing after breakdown that no exact value need be determined. For most small items the normal leakage current is well below a few hundred microamperes. This current climbs at the instant of breakdown to many milliamperes. Consequently, excellent results usually can be obtained by having a circuit breaker sensitivity or leakage light sensitivity in the neighborhood of 0.5 milliamperes to a few milliamperes.

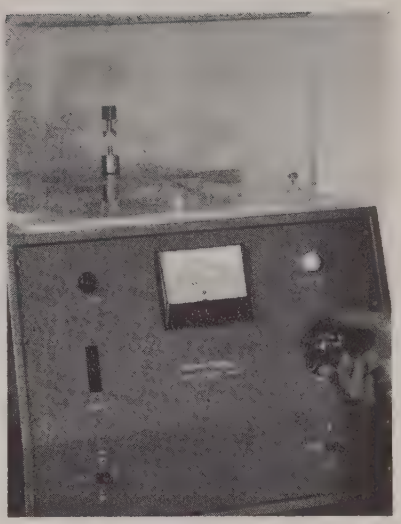

Figure 1, testing a sheet of insulating material per ASTM specifications D-149 using a 35 kv, 2 kva materials testing a-c high voltage test set. Note the standardized plug-in test jig and "Lucite" safety cage.

In recent years, high voltage direct current testing has become increasingly popular. With the elimination of the heavy a-c quadrature or capacitive current, the d-c test set need only supply the leakage current and the equipment size is reduced accordingly. It is not always easy to substitute a d-c test for an established a-c test in spite of the great deal of work done to determine the correlation betweent a-c and d-c testing. While there is agreement within some industries, there is total lack of agreement in others. Conversion factors (value of d-c test voltage equivalent to a given a-c value) ranging from one to one to as high as six to one are prevalent. However, most people performing tests on small items or materials are

gravitating toward a correlation value between 1.6 and 1.8 to one. When performing d-c high voltage tests, if the current is plotted as the voltage is raised the breakdown point may frequently be anticipated by observing a sudden change in the curvature of the plot. This abrupt change in slope preceding breakdown may vary from a gradual curve in some materials to a right angle bend in others. With the aid of such a plot the experienced test engineer can obtain valuable data.

Insulation Resistance Testing

Another exceedingly common electrical test is that of insulation resistance. While 500 volts has been pretty well standardized as the test voltage for making insulation resistance measurements, recently more and more insulation resistance tests are being made at both higher and lower voltages. Lower voltages are frequently used in making tests on semi-conductor devices while the use of higher voltages is an attempt to more nearly correlate insulation resistance and high voltage breakdown measurements, or to use the insulation resistance test as a substitute for a high potential dielectric strength test. It should be emphasized that an insulation resistance test cannot replace a high potential test, since the insulation resistance in general has little direct relationship to dielectric or breakdown strength. For example an actual void in the insulation may show an exceedingly high value of insulation resistance even though it might permit breakdown at a relatively low voltage.

In days of lower operating voltages, it was pretty much a rule of thumb that insulation resistance values of about a megohm were satisfactory. Now with thin film insulations, close clearances, higher voltages, and lower current operation, insulations in the neighborhood of thousands of megohms are common and in many cases necessary. Equipment to measure these values have kept pace with the requirements. While a number of years ago most insulation measuring sets had high ranges of only a few hundred megohms, there now are a good many that will measure into the millions of megohms. It should be remembered, however, that measurements in the millions of megohms must be taken with a grain of salt, unless proper laboratory conditions and precautions are met. A change in atmospheric conditions such as humidity or dirt content can affect the readings tremendously.

Except in research projects and in scientific applications, the exact measurement of insulation resistance is not as necessary as the order of magnitude of the resistance. In other words, the question is whether the insulation resistance is in the neighborhood of megohms, tens of megohms, or thousands of megohms. Whether it is 233 megohms or 349 megohms is usually rather unimportant. Of course, in the development of new materials, with tests performed under properly controlled conditions, high range megohm measurements take on new significance.

Corona Testing

Corona is an electrical discharge due to the ionization of the air in voids in the insulation or across or from the surface of the insulation under the stress of high voltage. There are two aspects of corona testing; first is the determination of or the investigation of the effect of corona on the life or performance of the insulation material, and second, the detection of the presence of corona during normal operation of equipment or during high voltage testing (especially in those cases where it has been previously pre-determined that corona is harmful to the insulation used).

Corona may be generated by any suitable high voltage test set by raising the voltage to the point where the corona discharge occurs. In earlier days the presence of corona was detected by sight or sound or for more sensitive requirements by the radiation picked up by an ordinary radio receiver. Newer types of corona testing equipment detect and display on an oscilloscope even minute traces of corona. These instruments embody a corona free high voltage supply, and a corona free high voltage capacitive divider network with associated filters to extract the corona signal present in the high voltage circuit. The signal is fed to the detector, basically a high gain wide band amplifier, feeding a high sensitivity oscilloscope. The oscilloscope is provided with special characteristics to properly display the corona signal. The corona may then be studied visually, measured with a built-in calibrator, or used to trigger an internal or external alarm. While most corona test sets utilize 60 cps a-c, experimental work is being done at other frequencies as well as with direct current.

As high altitude operation of electronic equipment becomes more commonplace, dielectric strength and corona testing take on added significance because of the lower voltage levels at which breakdown or corona occurs. Performing a high altitude test becomes extremely difficult though, because of the problem involved in feeding the high test voltage to a specimen in an altitude chamber. Normal techniques become very unsatisfactory and special setups must be devised for each particular case. There is room for considerable work in the development of techniques to facilitate these tests.

Test Standardization

One great need in the field of insulation testing is a more realistic approach and standardization of test methods and interpretation of test results. While the American Society for Testing and Materials has served this function in the field of insulation materials testing, there are no such established procedures in the testing of components or assemblies using these same insulation materials. In most cases where the paragraphs on high potential insulation resistance tests are incorporated in over-all equipment specifications, they are incomplete, unrealistic, and/or frequently obsolete. In this regard it should be noted that the specifications written by the recognized engineering agencies (ASTM, AIEE, etc.) do a much better job than those of most government agencies.

In a few areas the methods of test and interpretation of results have been rather well standardized. One

example is that of dielectric strength testing of insulation materials. ASTM specifications not only spell out the test procedure, but establish a degree of uniformity that makes it possible to compare materials tested at separate places or at separate times or to compare one material to another. The commonly accepted ASTM method consists of utilization of a standard test jig and an alternating current high voltage supply. Standard methods of raising the voltage are described and the test result is given in terms of the average breakdown voltage of a number of samples. This type of carefully engineered specification enables the establishment of industry accepted tests and reports.

Certain segments of the cable industry are standardizing on the methods of performing acceptance, proof, or maintenance tests. High potential d-c is used and the usual method of reporting results is to plot the leakage current as a function of test voltage. Modern equipment is required as sensitive current metering with ranges of only a few microamperes are frequently necessary. By using d-c, failure or breakdown is frequently preceded by a sharp bend (or knee) in the curve and the test may be stopped at that point. However, there is still no general agreement concerning acceptable voltage or current limits.

The method of production high voltage testing of small consumer type items has also been fairly well standardized. It consists of applying a voltage equal to twice operating voltage plus a thousand volts between the live terminal and frame of the product. A collapsing field type high voltage test set using a neon leakage indicator (most frequently set to glow at about 0.5 MA) is usually used. Some of these test sets have an additional neon lamp to indicate the presence of RF current such as those caused by actual sparking.

Education

Another problem in the field of electrical testing of insulation materials is that of education. There is a wide-spread lack of knowledge of testing techniques, of interpretation of test results, and even of the tests desirable or necessary. The effect of quadrature capacitive current as distinguished from leakage current is frequently misunderstood. The attempt to use an insulation resistance test instead of a high voltage test is quite prevalent. There is a wide-spread lack of agreement even among the experts as to the relative merits of a-c or d-c testing. The evaluation of results of an arc test is frequently inconsistent. There is wide-spread disagreement as to the proper frequency most suitable for corona measurements. There is unreasonable insistance on the part of many old timers on obsolete test methods and techniques. Many specifications are unnecessarily restrictive in that they describe a particular piece of test equipment rather than the specific test requirements, and in too many cases, the equipment described is rather primitive compared to some of the newer instruments. There is a regrettable tendency on the part of some of the equipment manufacturers to continue producing equipment that does not take advantage of the advances in the state of the art. Most serious of all is the lack of appreciation on the part of management in many companies of the importance of proper testing. In many cases there is a lack of understanding of the inherent dangers in certain types of high voltage tests, and lack of stress of proper safety precautions.

In a large part, the state of the art has advanced to the point where test equipment is available and may be supplied to perform almost any of the tests required on the new materials, or to assist in the development of more advanced materials. Unfortunately too little thought is given as to exactly what information is being sought, what measurement will yield that information, and how to interpret the test results obtained and correlate it so that use may be made of the information in the over-all program. Tremendous strides have been made in many areas. Many organizations have equipment and manpower capable of doing the job required, but in too many of the smaller organizations non-electrically oriented or untrained men with inadequate equipment have the responsibility.

The hope of the future must lie not only in further education of the men developing and using the insulation materials, but also in the education of those writing the specifications for the equipment in which insulation plays so important a part. Then testing will play its most significant role.

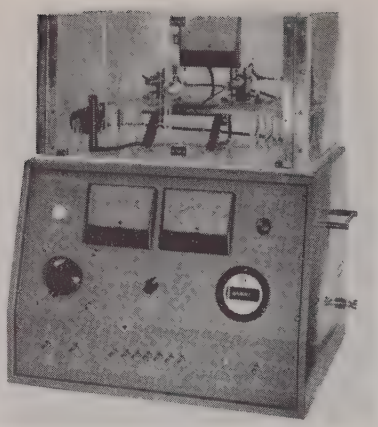

Figure 2, arc resistance tester, a high voltage test set specifically designed for testing the ability of solid electrical insulating materials to resist the action of an arc close to the surface.

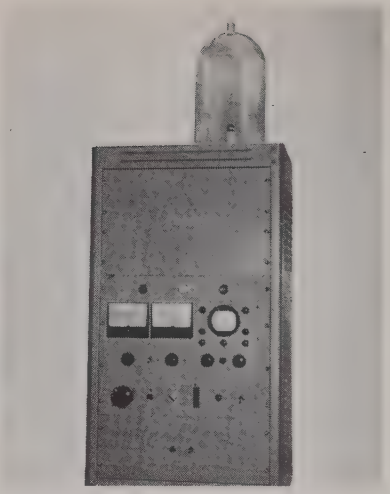

Figure 3, special direct current corona test set with built-in vacuum chamber and pump for simulated high altitude testing.

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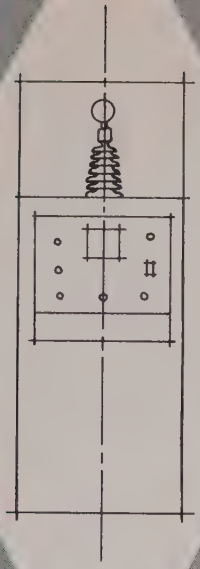
Bulletin 10-1.3



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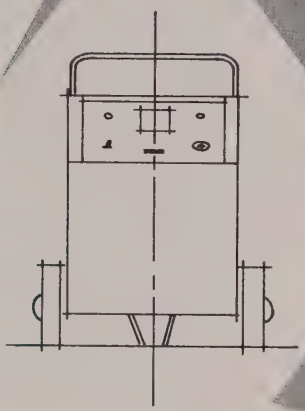

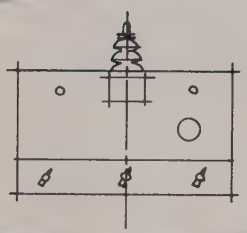

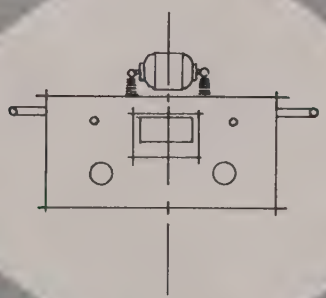

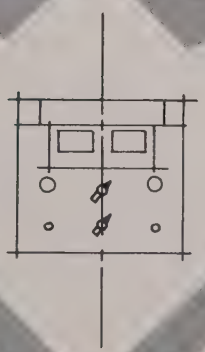

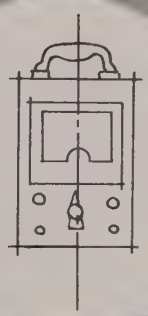

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Founded in 1936 by James F. Inman, Associated Research, Inc., has developed a wide range of instrumentation for measurement of resistance, insulation leakage current, dielectric strength and allied applications.

This CONDENSED CATALOG lists the following basic instruments and services:

Special Instrumentation	page 3
HYPOT® Dielectric Strength Test Sets	
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Console & Mobile Models	page 5
Cable Fault Locator	page 5
Bench & Portable Models	page 6
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Insulating Oils Tester	page 7
Arc Resistance Tester	page 7
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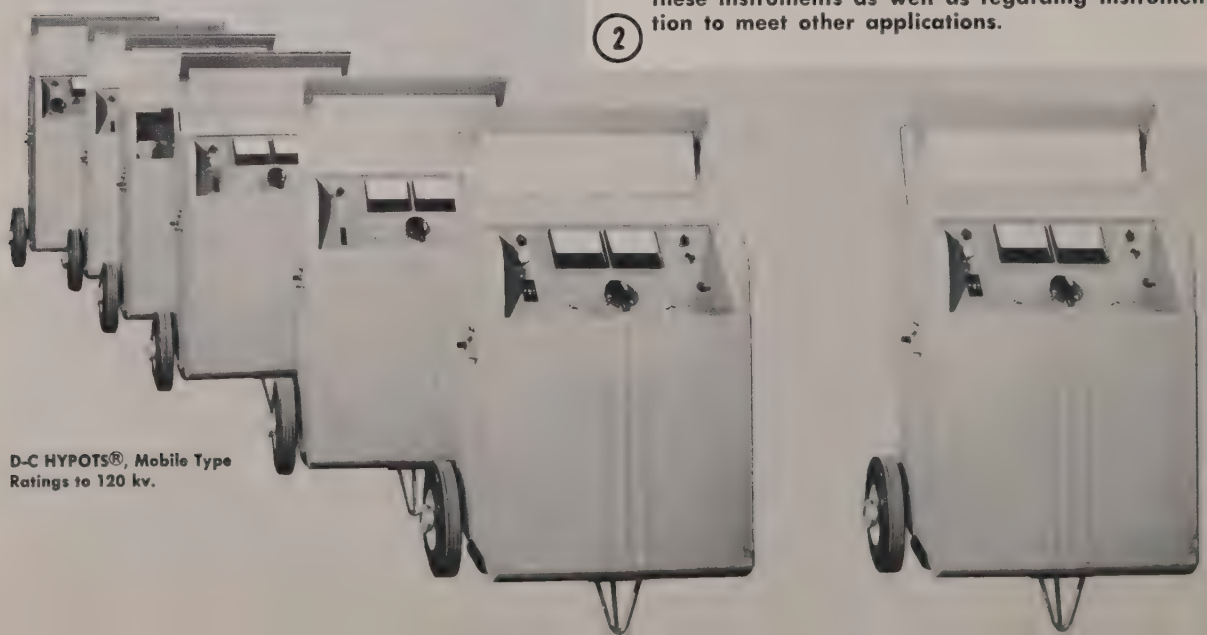
Sphere Gap Assemblies	page 10
Automated Testers	page 11
Current Transformers for Metering	page 11
Polygraph (Lie Detector)	page 11

You are invited to write for detailed specifications on these instruments as well as regarding instrumentation to meet other applications.

D-C HYPOT®, Console Type
Ratings to 150 kv.



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Custom designed automatic high voltage circuit and component analyzer. Supplied to wire manufacturer for dielectric strength, insulation resistance and continuity testing of 120-conductor cable.

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Our engineering and production facilities are available for the design and manufacture of special test equipment, sold under private label by nationally known industrial organizations. Inquiries regarding your needs are invited.

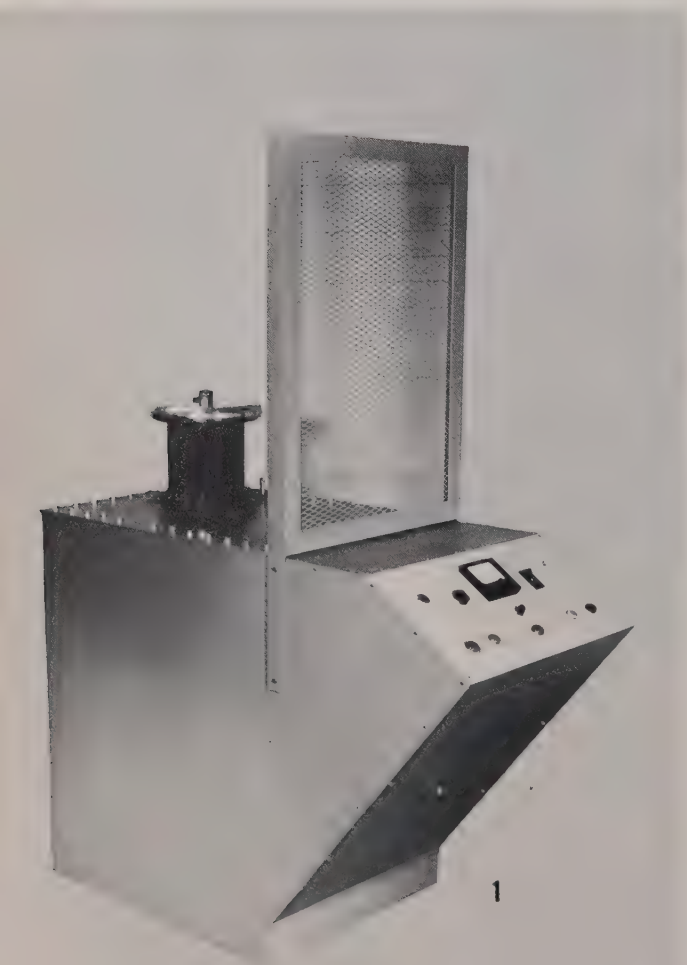
Production testing of control circuit components for high voltage breakdown and insulation resistance. On right, the HYPOT® Jr. and on left, the VIBROTEST® megohmmeter.

High Voltage Breakdown Testing . . A-C or D-C

A full range of instrumentation for non-destructive breakdown tests is offered. Pages 4, 5, 6 and 7 of this catalog describe each basic series. Page 11 gives data on automated systems for dielectric strength testing. Page 3 refers to instrumentation combining dielectric strength testing with tests that are frequently made concurrently.

Our experience as one of the largest and best equipped producers of heavy duty dielectric test sets has shown the need for wide variations in the facilities to be embodied in the individual test set.

Thus, basic HYPOT® designs presented on these pages are essentially for reference. Additional facilities required for specific applications may be incorporated. Many of the useful features described are available only in HYPOT® test sets. Provisions for material and equipment testing in accord with applicable ASTM, MIL, and Federal Specifications are provided by suitable HYPOT® models.



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Very High Voltage D-C HYPOTS® . . 150 to 250 KV

These test sets are available with ratings of 150 kv to 250 kv, and maximum current outputs of 2, 5, 10 or 25 ma. Operating controls may be located on the main cabinet similar to Fig. 1, or in a separate bench cabinet. Output is through a heavy-duty, oil-filled, corona-free bushing.

Standard features include: 4½" Kv meter connected directly across high voltage output; 4½" electronically protected multiple range current meter; metered return and bypass guard circuits to measure load (leakage) current or bypass (guard) current; long-life selenium rectifiers; fast-acting magnetic circuit breaker for protection of high voltage circuits and external load; primary circuit protected by thermal overload breaker. Additional safety provisions include zero-return interlock, connector for remote interlock, cabinet and panel at ground potential, grounded screen between operator and high voltage bushing.

Optional features include: Automatic rate of voltage rise, adjustable high limit shut off controlled by voltage or current; corona pick-up and detector; kilovoltmeter memory circuit to retain reading of breakdown voltage; multiple output voltage measuring ranges; vacuum tube microammeter with ranges as low as 2 microamperes full scale. Additional features are described in special bulletin.

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Standard features include: Rectifier type 4½" kilovoltmeter directly across the high voltage output. Housed in heavy steel, caster-mounted cabinet (Fig. 1). Cabinet and panel are at ground potential. Grounded safety screen is between the high voltage bushing and the operator. Additional safety features include: Zero return interlock; connector for remote interlock; fast acting magnetic breaker in output to protect high voltage circuits and load; primary circuits protected by thermal overload breaker.

Optional features include: Multiple kilovoltmeter ranges; single or multiple range output current meter; dual range or adjustable secondary overload circuit breaker; adjustable high limit shut off for voltage or current; kilovoltmeter memory circuit to maintain reading of breakdown voltage; automatic control for rate of rise with pre-set dwell; corona pick-up and detector; control section in separate bench type cabinet; and others detailed in special bulletin.

Automatic Rate of Rise Control . . . Most of the A-C and D-C HYPOT® models may be equipped with automatic control to raise or lower the output voltage at a predetermined rate as required by many test specifications. Single speed, multiple speed or continuously adjustable options are available. Timer to permit presetting dwell period may also be included. Full description will be obtained by requesting bulletin.

HYPOTS®

Console A-C HYPOTS® . . 75 KV, 5 KVA

Models have outputs continuously variable from 0 to 30 kv, on up to 75 kv, at ratings of 1, 2, or 5 kva. Housed in caster-mounted steel cabinets finished in baked grey hammertone, with aluminum control panels in blue hammertone. Dimensions: 21¼" wide, 25½" deep plus 10" for control panel, 51" high plus 20" to top of protection screen. Weights from 600 to 1100 pounds. (Fig. 2). Standard and optional features include those listed for the "Heavy Duty A-C HYPOTS®" on the preceding page.

Console D-C HYPOTS® . . to 150 KV, 10 MA

For non-destructive testing of insulating materials, cables, transformers, switchgear, motors and generators. Outputs continuously variable from 0 to 100 kv through 150 kv, with standard current ratings of 2.5, 5, and 10 ma at maximum voltage. Lower voltage and/or higher current units are available.

The caster-mounted console cabinets are similar to those of the "Console A-C HYPOTS®" described above. Weights from 650 to 850 pounds. Standard and optional features include those listed for the "Very High Voltage D-C HYPOTS®" on the preceding page.

Mobile A-C HYPOTS® . . to 30 KV, 10 KVA

Mobile A-C HYPOTS® for testing large rotating machinery, line materials, short lengths of cable, and insulating materials.

Available with outputs continuously variable from 0 to 5, 10 and 20 kv at ratings of 1, 2, 5 or 10 kva. 30-kv models can be supplied with ratings of 1, 2, and 5 kva. Input is 115 v for 1- and 2-kva models, and 220 v for 5- and 10-kva models.

Standard features include: Rectifier type 4½" kilovoltmeter directly across high voltage output; zero return interlock; connector for remote safety interlock; high voltage circuits and external load protected by fast-acting magnetic circuit breaker; primary circuit protected by thermal overload breaker; cabinet and panel at ground potential.

Housed in a welded steel cabinet with cable reel, detachable push-handle and semi-pneumatic wheels. Dimensions are: 23" wide, 21" deep, and 41" high. Weights range from 150 to 250 pounds. (Fig. 3).

Optional features include: Multiple kilovoltmeter ranges, milliammeter, secondary overload circuit breaker with adjustable limit or dual range, and burn test circuit.

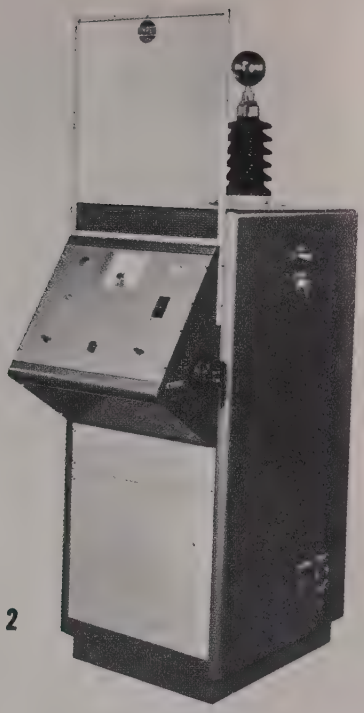
Mobile D-C HYPOTS® . . to 120 KV, 10 MA

Heavy-duty mobile test sets for determining insulation leakage and dielectric strength of cables, bushings, switchgear, transformers, motors and generators . . . on the factory floor, outdoors, or in mines and quarries.

Outputs continuously variable from 0 to 45 kv and on up to 120 kv, with ratings of 2.5, 5, 10 ma, at full voltage. Operate from 115 v, a-c. High voltage receptacle may be oil filled for corona-free connection. The mobile cabinets are similar in design and dimensions to those listed for the "Mobile A-C HYPOTS®." Weights range from 285 to 450 pounds.

Standard features include: 4½" kilovoltmeter connected directly across the high voltage output; three-range 4½" microammeter electronically protected against overload; zero return interlock; connector for remote safety interlock; fast-acting magnetic circuit breaker in output to protect high voltage circuits and external load; thermal overload breaker to protect input circuits; long-life selenium high voltage rectifiers; metered return and bypass return terminals for measurement of load (leakage) or bypass (guard) currents.

Optional features include: Multiple output voltage ranges, vacuum tube microammeter with ranges as low as 2 microamperes, full scale, reversible polarity, adjustable high limit shut off for voltage and current.



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"Thumper" Cable Fault Locator

"Thumper" Cable Fault Locator converts the high voltage, low current output of a d-c high potential test set into high-voltage (up to 25 kv) high-current impulses to allow ready location of faults in electrical power cables. The frequency and intensity of the high-current impulses are adjustable while the "Thumper" is in operation. A 25-kv model is available as an accessory unit for use with suitable high potential d-c testers. Smaller units may be incorporated as a built-in feature in many of the D-C HYPOTS®. Descriptive bulletin is available.

Bench and Portable Models

Bench Type D-C HYPOTS® . . to 45 KV, 25 MA

Output voltages continuously adjustable, zero to maximum of 5 kv to 45 kv, and full load current ratings of 100 microamperes to 25 milliamperes or more. The steel bench-type cabinet is same as described for Bench Type A-C HYPOTS®. (Fig. 6).

Standard features include: 4½" kilovoltmeter directly across the high voltage output; three-range current meter electronically protected against damage from overload; fast-acting circuit breaker in output; thermal overload breaker in primary; long-life selenium rectifiers; grounded panel and cabinet; zero return interlock; connector for remote safety interlock; metered return and by-pass return terminals allowing measurement of either load or guard currents.

Optional features include: multiple voltage ranges; adjustable circuit breaker; vacuum tube microammeter with ranges as low as 2 microamperes, full scale; adjustable high limit voltage or current shut off; and automatic rate of rise (see page 4).

Bench Type A-C HYPOTS® . . 35 KV, 2 KVA

These high potential test sets are suited for dielectric strength testing of insulating materials, sample lengths of wire and cable, and components . . . having relatively low distributed capacitance.

Outputs available continuously variable from 0-10 kv, up to 0-35 kv, at 1 or 2 kva rating. The steel cabinet is finished in grey baked hammertone, and sloping aluminum panel in blue hammertone. Dimensions are: 20" wide, 16¼" deep at base, and 14¾" high plus output bushing. Weights from 70 to 100 pounds. (Similar to Fig. 6).

Standard features include: 4½" kilovoltmeter directly across the high voltage output; cabinet and panel at ground potential; fast-acting circuit breaker in output and thermal overload breaker in primary; zero return interlock; connector for safety interlock.

Optional features include: multiple kilovoltmeter ranges; output current meter with single or multiple ranges; dual range or adjustable secondary overload circuit breaker; adjustable leakage indicator light; automatic rate of rise control (as described on page 4).

Portable D-C HYPOT® . . 5 KV, 2 MA

Output of the Model 5205 Portable D-C HYPOT® is continuously variable from 0 to 5000 v d-c, metered in the output circuit. Measures leakage current as low as 0.05 microamperes over four scale ranges: 0-2, 20, 200 and 2000 microamperes.

Operates from 115 v a-c, with selenium rectifier providing up to 15 ma for rapid charging of capacitance loads. The welded steel case has a removable lid and carrying handle. Measures: 13½" wide, 13" high, and 7" deep. Weighs 24 pounds. Descriptive bulletin available.

"HYWATT" A-C HYPOT® Jrs. . . to 10 KV, 2 KVA

For a-c dielectric strength testing to 10,000 v at 2 kva, this HYPOT® series offers economy and the convenience of a compact bench-type cabinet. (Fig. 5). Models are available with output continuously variable from 0 to 1500 v up to 10,000 v a-c, at continuous duty ratings of 0.5 to 2 kva (approximately double for intermittent duty).

Features include: 4½" kilovoltmeter connected across the output, overload protection in output and primary circuits, high voltage "ON" switch allows momentary or sustained application of test potential. Descriptive bulletin available.

A-C HYPOT® Jrs. . . to 10 KV, 230 VA

Portable a-c dielectric strength testers providing outputs continuously variable from 0-1500 v up to 10,000 v a-c. Use of neon breakdown and leakage current indicators in conjunction with collapsing field-type high voltage transformers results in an instrument that is rapid and safe for production testing.

The leakage current indicator is adjustable from 0.3 to 3 ma. A 4½" kilovoltmeter directly across the high voltage output provides high accuracy. Short-circuit current cannot exceed 18 ma. The cabinet and panel are at ground potential. (Fig. 4).

Optional features include: Leakage indicator light adjustable to as low as 0.1 ma or as high as 5 ma; retractable tip or stationary test prods. Detailed specifications for each model are available.

D-C HYPOT® Jrs. . . . compact, portable insulation leakage current testers have high voltage selenium rectifier, providing output variable from 0-1500 v, and up to 5000 v d-c at 2 ma. Short-circuit current limited to 15 ma. Case and panel similar to illustration for A-C HYPOT® Jr. Descriptive bulletin available.

HYPOT® Jr. Automatic "Squawker" Models

Available with output voltages from 0-1500 volts to 0-6000 volts a-c. These units are similar to the standard HYPOT® Jr. models except that an audible signal unit and external control terminals are included, which operate simultaneously with the visual indicator.

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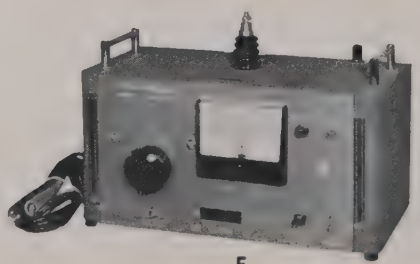

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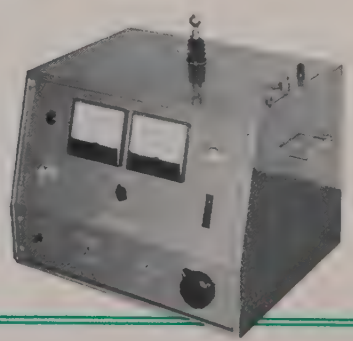


HYPOTS® for Special Applications

Insulating Materials Testers

Listed below are representative ARI testers for solid and liquid insulating materials. Due to the rapid progress of insulating materials and testing techniques, new equipment is added whenever required to meet ASTM, MIL and Federal test specifications.

Model 4712 Oil and Materials Tester

Provides 0 to 60 kv at 2 kva a-c, to test insulating oils and materials. Complete with safety interlocked test cage, oil cup and U.S., English and German standard electrodes. The rapid-acting magnetic breaker in the output has two sensitivity settings, facilitating tests at lower voltages. Housed in steel console cabinet with panel and cabinet grounded for operator safety.

Model 4510 Insulating Materials Tester

Test potential continuously variable from 0-50 kv a-c, at 2 kva. Numerous automatic control features facilitate testing insulating materials.

Test cage of transparent plexiglas accepts all ARI materials test fixtures and is safety interlocked to allow full view of the sample under test. Caster-mounted console cabinet. (Fig. 10).

Motor-driven rate of rise is adjustable from 300 to 3000 volts per second. Also dwell time on test sample is timer controlled and adjustable. The output kilovoltmeter has an electronic memory circuit retaining the indication on the voltage at which breakdown occurred. Descriptive bulletin available.

Model 4501 Materials Testing HYPOT®

Meets the dielectric strength testing requirements of Specification D-149, ASTM Standards on Electrical Insulation Materials. (Fig. 9). Output continuously variable from 0-35 kv a-c at 2 kva (intermittent rating). Magnetic breaker trips when specimen breaks down. Output termination in jacks at center of the lucite cabinet top accepts the interchangeable ARI materials testing fixtures. Optional features: interlocked clear lucite test cage and selection of ARI plug-in materials testing fixtures, automatic rate of rise, dual sensitivity circuit breaker, etc.

Model 4505 Insulating Oils Tester

Provides dielectric strength testing of insulating liquids in accordance with ASTM and Federal Specifications. REA approved. Output is continuously adjustable from 0-35 kv at 2 kva, a-c. Other voltage and power ratings are available. (Fig. 8).

Has 4½" rectifier type kilovoltmeter, magnetic breaker in output, zero return interlock, removable oil cup with standard ASTM 1" adjustable flat electrodes, bench type cabinet and carrying handle. Measures: 16" wide, 8½" deep and 8" high. Weight: 42 pounds. Motor driven rate of rise, dual sensitivity breaker and lucite test cage may be supplied. Descriptive bulletin available.

Model 8540 Arc Resistance Tester

Tests arc resistance of solid insulating materials in accord with ASTM Specification D495-58T. Arc intensity and duration are adjustable. Internal blower for exhaust fumes. Jig for sharpening test electrodes is included. Descriptive bulletin available. (Fig. 7).

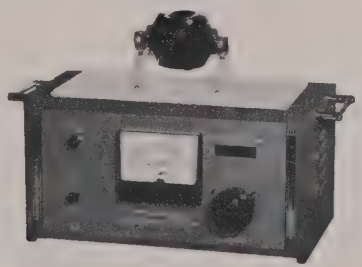
Corona Test Equipment

Detects and displays the presence of corona on built-in oscilloscope—caused by internal voids, insufficient clearances or other defects in material or equipment.

Equipment includes: specially constructed corona-free HYPOT® test set; a pick-up device to extract the true corona voltage; and the corona detection display unit. These sections are available as individual units or as an integrated package built into the ARI standard deluxe control cabinet. Outputs of 20, 30 and 35 kv are standard, although up to 100 kv may be supplied.

HYPOT® Power Supplies

HYPOT® designs provide a wide range of power supplies for special applications. D-C outputs to 250 kv and a-c outputs to 150 kv are available with current ratings from microamperes to amperes. Regulation and ripple characteristics can be supplied to suit your needs. A wide choice of housings is available.



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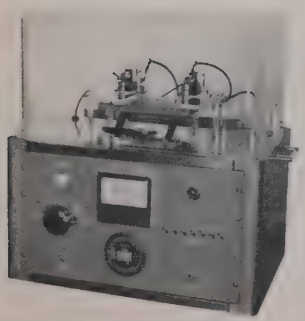

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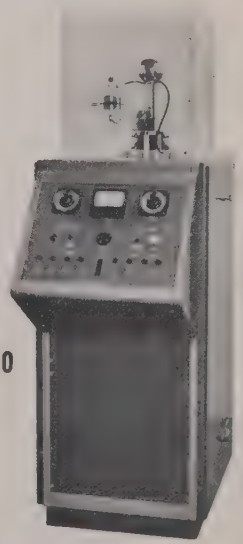


10

VIBROTEST® Megohmmeters

Measure Insulation Resistance to FIVE MILLION Megohms

11

The Modern Megohmmeter

Model 2570 VIBROTEST® Megohmmeter is a portable, a-c line-operated instrument providing direct-reading measurement of resistance to 5,000,000 megohms at 500 v d-c test potential.

There are six scale ranges: 1 to 50, 10 to 500, 100 to 5,000, 1,000 to 50,000, 10,000 to 500,000 and 100,000 to 5,000,000 megohms.

The 4½" rectangular meter is calibrated from 1 to 50 megohms. The power supply uses long-life selenium rectifiers, eliminating batteries or cranking. Use of five gas diode regulator tubes assures constant test voltage despite line voltage variations from 105 to 130 v.

The instrument has a welded steel case finished in grey hammertone and a removable lid with carrying-handle. Size is 8⅞" by 6" by 8½". Weight, 11 pounds. (Fig. 11). Descriptive bulletin is available.

Model 250 VIBROTEST® Megohmmeter is similar to the Model 2570, except that four megohm measuring ranges are provided: 1 to 50, 10 to 500, 100 to 5,000 and 1,000 to 50,000 megohms.

12

VIBROTEST® Megohmmeters

for Maintenance and Production Testing

A wide selection of direct reading, push-button operated megohmmeters is available in the various VIBROTEST® models that are designed for maintenance and production testing of insulation resistance. Many incorporate low ohms ranges for measuring continuity as well as ranges for measuring a-c and d-c voltages.

Operation is from self-contained batteries which, through a unique synchronous vibrator circuit, produce test potentials of 125 to 1000 v d-c for dependable measurement of insulation resistance. All models are housed in welded steel portable cases with carrying handle and removable lid. Case and lid are finished in grey hammertone, with the panel in blue hammertone. (Fig. 12).

Special models are available for the specific requirements of electric utility service, railway control and signal (to A.A.R. Specifications) and for marine use. Complete descriptive bulletins are offered.

HOSPITAL OPERATING ROOM SAFETY . . . The VIBROTEST® Model 269 has been designed to meet N.F.P.A. Specifications for measuring conductivity of hospital operating room flooring, conductive footwear, castors and other devices to assure safety from explosions resulting from electrostatic discharges. Descriptive bulletin available.

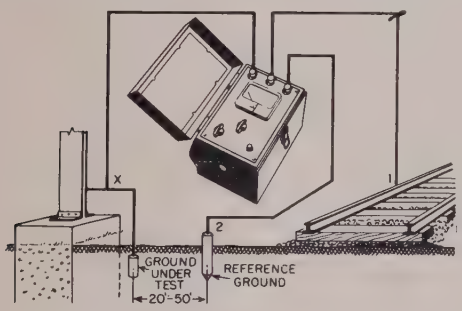
VIBROGROUND® . . Measure Ground Resistivity

Resistance of Man-Made Grounds

VIBROGROUND® is the fast, accurate way to test man-made grounds for electrical and electronic systems. Ground resistance measurements made with VIBROGROUND® are direct reading and require no computations.

These instruments provide readings of actual resistance to earth of the ground connection, unaffected by stray a-c or d-c voltages and currents, as well as by length of test leads, resistance of prods and general soil conditions. All models are push-button operated with self-contained batteries and synchronous vibrator power supply. No cranking or leveling.

VIBROGROUND® Models 251, 255 and 259 provide ranges covering every requirement by utilities, telephone companies, lightning protection engineers and similar applications for measuring man-made grounds. Descriptive bulletin available.



For Corrosion Control Engineers

. . push-button measurement of soil resistivity, anode resistance, circuit resistance, polarization effects

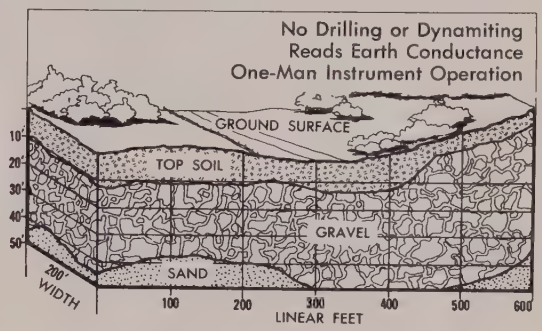
VIBROGROUND® Models 263A and 293 provide lightweight, accurate instruments for dependable measurement of soil resistivity and ground resistance . . . that operate from self-contained batteries and synchronous vibrator power supply. Complete accessories are available for two, three and four electrode methods of measurement.

Selector switch choice of ranges: 0-1, 0-10, 0-100 and 0-1000 ohms on the Model 263A and 0-1, 0-10, 0-100, 0-1000 and 0-10,000 ohms on the Model 293. Housed in welded steel case with removable cover and carrying handle. Weight 10 pounds with cover removed. (Fig. 13). Descriptive bulletin available.

Geophysical Subsoil Exploration

Electrical geophysical subsurface exploration through the use of the several VIBROGROUND® models designed for such applications . . . has received wide acceptance in many fields ranging from prospecting for mineral ores to determining subsoil profiles in connection with highway, bridge, pipe line and building construction. One of the most important applications is the wide use in highway construction and location of gravel deposits.

The VIBROGROUND® instruments for geophysical exploration provide direct readings of soil resistivity (in the case of the Model 274M, soil conductance) and are available with suitable accessory equipment for all methods of testing. These instruments are self-contained, light in weight and operate from a self-contained battery through the unique synchronous vibrator power supply. Descriptive bulletin available.



The "MICHIMHO" VIBROGROUND®

The above illustration is a subsoil profile prepared from soil conductance readings taken with the Model 274M "MICHIMHO" VIBROGROUND® . . . developed to utilize the Barnes Layer Method of subsoil determination.

This world-recognized procedure for determining the profile of subsoil layers provides data for solution of problems connected with location of highway grades, bedrock determinations, drainage slopes, and location of sand and gravel pits. The low cost of these determinations and the speed with which they can be made affords an important advance over seismographic methods and test drilling. (Fig. 14). Complete descriptive bulletin available.

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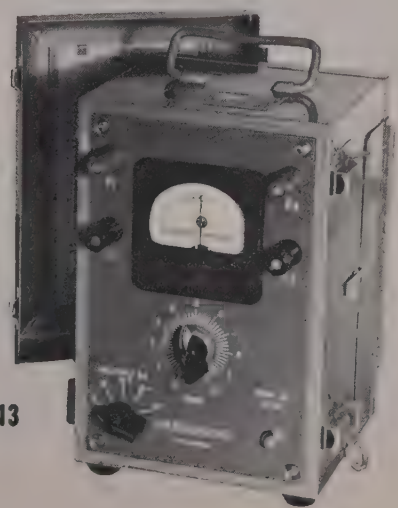


13

Instruments for Special Applications

Automated Production Test Resistance Bridges

Model 8516 "Pilotal" Ohmmeter automatically measures resistance to close tolerances and rejects when high or low limits are exceeded, by means of indicator lights. It also actuates circuits for automatic rejection, discriminating between samples that are on the high or low side. Figure 15 illustrates the Model 8516 as set to reject with 1% accuracy at a low limit of 3.75 ohms and a high limit of 4.00 ohms. The instrument may be supplied to accept or reject at resistance values from a fraction of an ohm to 5 megohms. Test voltage is low to assure operator safety. Complete application data is available on request.

Model 8513 Pilotal Resistance Bridge may be preset for any resistance value from 1 ohm to 10 megohms (accuracy better than .1%). Models may be provided with separately adjustable high and low limits from .2% to 20%.

Automated Production Test Capacitance Bridge

Model 8529 Pilotal Capacitance Bridge shown in Fig. 16, permits automatic production testing of all types of capacitors. Center value adjustable from .001 to 1 microfarad with preset acceptance limits of ± 1% to operate go and no-go lights. Models may be furnished incorporating separately adjustable high and low limits from .5 to 20%.

Phase Sequence Indicator

A miniaturized pocket portable instrument that provides positive phase sequence indications when connected to three-phase power sources. The instant readings not only assure proper rotation of motors but guard against costly damages. This instrument weighs only 11 ounces and measures 2⅞" wide, 1⅝" deep and 4" high.

Model 40 is designed for use on 60-c circuits, and Model 44 is for use on 400-c circuits. (Fig. 17).

Portable Precision Ohmmeter

accurate to ½ of 1%

The accuracy of ½ of 1% provided by these ARI Precision Ohmmeters is up to four times improved over that of usual portable instruments . . . yet they are direct reading and retain their accuracy under severe usage.

Compensation is provided for changes in resistance of leads and battery. The welded steel case and removable cover are finished in baked grey hammertone. (Fig. 18).

Model 244 provides ranges: 0-50/500/5,000/50,000 ohms, permitting readings as low as 0.05 ohm.

Model 246 provides ranges: 0-100/1,000/10,000/100,000 ohms with readings as low as 0.1 ohm.

Sphere Gap Assemblies

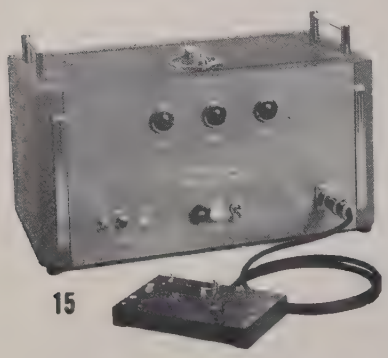
This is one of the few recognized standards for measuring high voltage. Since the calibration accuracy of a sphere gap depends upon physical configuration rather than upon electrical characteristics of the components, calibration accuracy may be positively determined by use of this device.

The ARI Sphere Gap Assembly consists of the sphere gap with micrometer gap adjustment (direct reading in inches or centimeters) and a current limiting resistor assembly. Models are available to measure potentials from 30 to 150 kv. (Fig. 19).

Portable Kilovoltmeters

These portable kilovoltmeters measure true peak (positive, negative or both) rms, or d-c . . . or any combination of these in single or multi ranges.

Ranges from 10 to 150 kv peak or d-c, and from 10 to 110 kv rms are available. Accuracy is better than 3% of full scale. Current drawn from a circuit under test is less than 0.5 ma. (Fig. 20). The ARI Engineering Staff will supply additional data on your application.



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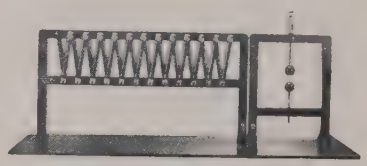

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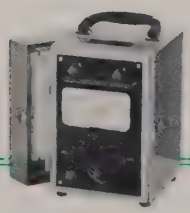

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16

Automated Operation of Tests for Components, Cables, Materials

The ARI Engineering Staff is prepared to design and build special purpose complex automatic sequence and sensing test systems that embody high potential breakdown, insulation leakage current measurements, continuity and associated tests.

Figure 22 shows a special HYPOT® arranged to sequentially test fifty items or circuits in a single assembly at d-c potentials up to 4000 v. The position under test is indicated on a counter. When leakage current exceeds a preset level, the tests stop simultaneously with the illumination of a warning light and sounding of an alarm.

The Model 8515 Automatic Capacitor Tester Fixture may be used in conjunction with the Model 8514 Automatic HYPOT®. This is a fully automated system for life testing 50 capacitors, with memory provision, cut-out of failures, fully motorized control of voltage rise, preset dwell time for high voltage test and many other unique facilities.

The Model 8524 High Voltage Automatic Analyzer, Fig. 21, and also illustrated on page 3, provides facilities for completely automated continuity, insulation resistance and dielectric strength testing of up to one hundred and twenty cable conductors, assembly circuits or components.

A bulletin is available detailing many more unusual systems for automated testing that have been designed and produced by Associated Research, Inc.

21

Current Transformers for Metering and Allied Applications

"Donut" type current transformers for metering and allied applications are available in turns ratios of 10/5 to 5,000/5 at burdens of 2.5 to 30 va and higher. Frequency response is from 25 to 400 cycles; insulated for 4000 v a-c; ratio accuracies of 1% are standard.

Inside diameter varies from 1⅝" to 3½", depending upon the model. However, any size or shape may be supplied to fit the customer's requirements.

The "Donut" current transformers are of the inserted primary type for positioning over the conductor or bus bar. Two secondary output leads are provided for direct connection to the meter or other external circuit. (Fig. 23).

22

23

The Keeler Polygraph (Lie Detector)

For twenty years Associated Research, Inc. has led in the development and manufacture of the polygraph, as an instrument essential to public safety and progressive law enforcement.

Today, ARI's Keeler Polygraph has become an important adjunct to industrial security and employee relations programs. If you would like more information on this subject, please write. (Fig. 24).

24

ASSOCIATED RESEARCH, INC.
3758 WEST BELMONT AVENUE • CHICAGO 18, ILLINOIS

These ARI Application Bulletins Offer Important Data on Use of Modern Instruments

D-C HYPOT® Insulation Testing.

• •

Predict Motor Failure with Periodic Insulation Resistance Tests.

• •

High Potential Dielectric Strength Testing with HYPOT® Jrs. and Automatic "Squawker" HYPOTS®.

• •

Practical High Potential Testing.

• •

Insulation Resistance Measurement with the VIBROTEST®.

• •

Manual on Testing Insulating Materials.

• •

Your inquiry will be appreciated for application data on any aspect of high voltage breakdown testing, insulation resistance or dielectric strength measurement.

HIGH POTENTIAL DIELECTRIC STRENGTH TESTING WITH HYPOT JUNIORS AND AUTOMATIC SQUAWKER HYPOTS
INSULATION RESISTANCE Measurements with the VIBROTEST®
ASSOCIATED RESEARCH INSTRUMENT APPLICATION NOTES
PREDICT MOTOR FAILURE
Geophysical Subsoil Exploration as an aid to the Engineer
MANUAL on TESTING INSULATING MATERIALS
ASSOCIATED RESEARCH, Incorporated
3758 WEST BELMONT AVENUE • CHICAGO 18, ILLINOIS
Portable HIGH VOLTAGE D-C Test Set
U.S. Steel's Gary Mill uses mobile DC tester
Practical Hi-Pot Testing
Electrical Manufacturing

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